

4. ORGANIC CONTAMINANTS

Carbon tetrachloride (CCl_4), tetrachloroethene (PCE), and methylene chloride have been identified as COPCs, primarily for the groundwater ingestion exposure pathway for OU 7-13/14. This section presents sampling results for those COPCs followed by sampling results for other organic compounds detected during monitoring.

4.1 Carbon Tetrachloride

The primary source of CCl_4 at the SDA is Series 743 waste drums shipped from RFP between 1966 and 1970 (Miller and Varvel 2005). Initially, 9,689 Series 743 waste drums were buried in multiple pits in the SDA, including Pits 4, 5, 6, 9, 10, 11, and 12. In the 1970s, all 1,015 drums from Pits 11 and 12 were retrieved, leaving 8,674 drums of Series 743 waste drums in the SDA. The estimated mass of CCl_4 contained in these 8,674 drums is $7.9\text{E}+05$ kg (Miller and Varvel 2005).

Carbon tetrachloride has been detected at the SDA in surficial sediments, vadose zone soil gas, vadose zone soil water (perched water and lysimeters), and the aquifer beneath and surrounding the SDA. Carbon tetrachloride vapor also has been detected emanating from the soil surface by surface isolation flux chambers.

4.1.1 Waste Zone

Carbon tetrachloride was detected in high concentrations in soil-gas samples collected from vapor probes placed in the waste in Pits 4 and 10. The samples were collected in Tedlar bags or SUMMA canisters using a glovebox and analyzed with an INNOVA Model 1314 photoacoustic multigas analyzer. Some of the field duplicate samples also were analyzed using standard laboratory gas chromatography and mass spectrometry (GC/MS) as an accuracy check on the INNOVA results.

In FY 2004, the probes were sampled quarterly and 10–13 probes produced a sample each quarter. Carbon tetrachloride was detected in all of the probes that yielded a sample. Table 4-1 presents results for CCl_4 and other VOCs for which analysis was performed. The maximum CCl_4 concentration measured was 79,600 ppmv at the 743-08-VP2 probe (4.1 m [13.4 ft] bls) in February 2004. The CCl_4 concentrations at this location are routinely greater than 30,000 ppmv, which is near the predicted equilibrium vapor concentration of CCl_4 in Series 743 sludge (46,000 at 10°C) and close to the pure component equilibrium gas-concentration value (71,000 at 10°C). This is indicative of relatively “fresh” Series 743 sludge or liquid-phase VOCs.

During the last two quarters of FY 2003, a divergence was detected in waste zone soil-gas sampling results between the INNOVA and the duplicate analyses performed using GC/MS. Until that time, there was good agreement (less than 10 percent) between the INNOVA and the GC/MS. The INNOVA was sent back for recalibration several times, but the discrepancy could not be resolved. Since that time, INNOVA results for CCl_4 have been from 20 percent to several times greater than the GC/MS results. This appears to be true for the FY 2004 results as well. This is unusual because the INNOVA is consistently lower than the standard gas concentrations. A plan for resolving the problem is being developed that includes an evaluation of the standard gases and all other sampling and analysis procedures.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities.

Table 4-1. Volatile organic compound vapor concentration results from Subsurface Disposal Area vapor probes in FY 2004.^a

Probe	Port Depth (ft)	Date Sampled	Sample No.	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)	1,1,1-TCA (ppmv)	TCE (ppmv)	PCE (ppmv)
743-03-VP1	19	11/11/03	IPV30701VA	272	49	15	75	15
		9/27/04	IPV35501VA	25 ^b	3 ^b	4 ^b	13 ^c	9 ^b
743-03-VP2	14	11/11/03	IPV30801VA	116	22	8	33	11
		5/27/04	IPV34001VA	50,100	5,370	1,650	656	218
		9/27/04	IPV35601VA	5,940	5,670	1,900	694	297
743-03-VP3	5	11/11/03	IPV30901VA	275	90	16	24	7
		2/17/04	IPV32501VA	5,970	861	274	1,090	1,120
		5/26/04	IPV34101VA	9,120	1,950	763	1,440	601
743-08-VP1	21	11/11/03	IPV31001VA	14,800	8,190	627	2,180	131
		2/17/04	IPV32601VA	73,100	13,900	1,340	4,970	3,680 ^c
		5/27/04	IPV34201VA	68,300	14,300	1,630	7,480	612
		5/27/04	IPV34201HU ^d	48,000	15,000	1,500	11,000	<150
		9/27/04	IPV35801VA	53,900	13,400	1,370	6,910	395
		9/27/04	IPV358013A ^d	38,000	17,000 ^c	1,700	13,000 ^c	140
743-08-VP2	14	11/11/03	IPV31101VA	502	210	20	38	1
		2/17/04	IPV32701VA	79,600 ^c	12,100	1,340	4,040	2,630
		2/17/04	IPV32701VT ^d	5,200	1,600	3,400	8,700	2,300
		5/27/04	IPV34301VA	55,700	10,100	1,220	3,260	356
		5/27/04	IPV34301HU ^d	44,000	12,000	1,400	11,000	150
		9/27/04	IPV35901VA	61,900	10,600	1,300	3,720	373
743-08-VP3	6	11/11/03	IPV31201VA	951	362	34	88	6
		2/17/04	IPV32801VA	25,700	5,560	590	2,330	1,650
		5/27/04	IPV34401VA	12,000	4,700	386	2,710	104
		9/27/04	IPV36001VA	17,400	4,570	472	1,790	108
743-18-VP1	21	5/27/04	IPV34501VA	144 ^b	57 ^b	6 ^b	90 ^b	8 ^b
		9/27/04	IPV36101VA	263 ^b	80 ^b	8 ^b	64 ^b	4 ^b
743-18-VP3	8	11/11/03	IPV31401VA	70	39	16	101	30
		2/17/04	IPV33001VA	18,000	3,770	468	1,660	1,140
		5/27/04	IPV34601VA	1,640	518	74	415	17
		9/27/04	IPV36201VA	3,190	673	127	395	20
743-18-VP4	15	11/11/03	IPV31501VA	8,220	1,200	283	1,400	40
		11/11/03	IPV31501VT ^d	620	100	39	130	18
		2/17/04	IPV33101VA	8,430	1,350	278	1,720	-6 ^c
		5/27/04	IPV34701VA	7,400	973	195	1,340	5
		9/27/04	IPV36301VA	9,730	1,340	266	1,490	12

Table 4-1. (continued).

Probe	Port Depth (ft)	Date Sampled	Sample No.	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)	1,1,1-TCA (ppmv)	TCE (ppmv)	PCE (ppmv)
DU-08-VP2	16	11/10/03	IPV30001VA	10,900	7,280	3,810^c	6,770	741
		2/17/04	IPV31601VT ^d	23,000	5,700	700	1,500	61
		5/26/04	IPV33201VA	17,000	5,720	3,050	5,700	1,980
		5/26/04	IPV33201HU ^d	2,300	700	1,600	3,600	650
		9/27/04	IPV34801VA	1,500	4,630	2,710	5,680	1,670
DU-10-VP2	11	11/10/03	IPV30201VA	4,510	1,730	2,030	3,390	1,360
		2/17/04	IPV31801VA	3,530	1,390	1,310	2,860	1,280
		5/26/04	IPV33401VA	4,560	1,270	1,270	2,380	1,260
		5/26/04	IPV33401HU ^d	1,300	220	540	750	140
		9/27/04	IPV35001VA	4,930	1,350	1,440	2,750	1,320
		9/27/04	IPV350013A ^d	2,700	780	1,700	3,800	1,800
DU-10-VP3	7	11/10/03	IPV30301VA	7,000	1,240	1,850	2,370	1,560
		2/17/04	IPV31901VA	3,910	797	1,095	1,760	1,080
		5/26/04	IPV33501VA	6,660	1,050	1,400	1,980	1,530
		9/27/04	IPV35101VA	8,060	1,540	1,700	2,680	1,790
DU-14-VP2	12	11/10/03	IPV30501VA	6,700	5,140	1,530	9,980	-382
		11/10/03	IPV30501VT ^d	2,800	1,800	1,300	6,800	250
		2/17/04	IPV32101VA	6,910	2,740	1,060	5,890	761
		5/26/04	IPV33701VA	11,400	3,300	1,170	6,810	915
		9/27/04	IPV35301VA	13,900	3,630	1,280	7,760	1,010
DU-14-VP3	5	11/10/03	IPV30601VA	699	515	312	703	273
		2/17/04	IPV32201VA	946	557	301	1,750	365
		5/26/04	IPV33801VA	2,250	946	519	2,030	446
		9/27/04	IPV35401VA	2,200	868	398	2,060	418

a. All analyses were performed with the INNOVA gas analyzer except where noted. The INL ECL analyses were performed with GC/MS.

b. Low sample volume, results unreliable.

c. **Bold font** indicates maximum measured concentration.

d. Duplicate samples in 250-mL SUMMA canisters analyzed using GC/MS by INL ECL.

e. Negative results are considered undetected.

GC/MS = gas chromatography and mass spectrometry

INL ECL = Idaho National Laboratory Environmental Chemistry Laboratory

PCE = tetrachloroethene

TCA = 1,1,1-trichloroethane

TCE = trichloroethene

4.1.2 Vadose Zone

4.1.2.1 Perched Water and Lysimeter. Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but insufficient water was available for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. Figure 4-1 shows the history of the CCl₄ concentrations in perched water in Well USGS-92. The decline in CCl₄ concentrations in Well USGS-92 since 1997 is attributed to operation of the OCVZ vapor vacuum extraction with treatment

(VVET) system, which began in January 1996. Well USGS-92 is located near vapor vacuum extraction Well 7V.

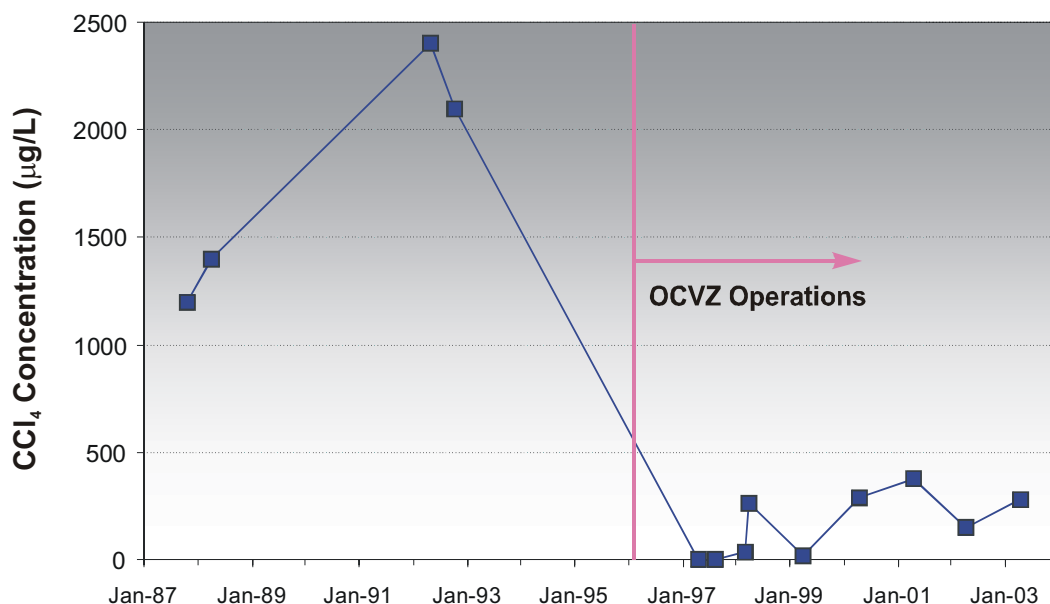


Figure 4-1. History of carbon tetrachloride concentration in perched water in Well USGS-92.

4.1.2.2 Soil Gas. Soil-gas monitoring in the vadose zone is accomplished using an extensive system of permanent soil-gas sampling ports inside and outside of the SDA boundary. The ports are made of stainless-steel tubing attached to the outside of well casings. The bottoms of the tubes are perforated and surrounded by sand. Figures 4-2a and 4-2b show the location of wells with soil-gas sampling ports in the vicinity of the SDA and the depths of the ports. The port depths range from a minimum depth of 4.6 m (15 ft) in Well WWW-1 to a maximum depth of 180 m (591 ft), just above the water table in Well M13S.

Over 1,800 vadose zone soil-gas samples were collected in FY 2004 and analyzed with a Brüel and Kjær photoacoustic multigas analyzer. Figure 4-3 shows the detection frequencies of CCl₄ for all samples. Nearly one-half of all detections were less than 10 ppmv, and 46 detections were greater than 1,000 ppmv. The complete set of soil-gas data for FY 2004 can be found in three reports:

- *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2003* (Housley 2004)
- *Environmental and Operational Mid-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2004* (Housley and Sondrup 2004)
- *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project—2004* (Housley 2005).

The maximum CCl₄ concentration measured in FY 2004 was 4,030 ppmv in Well 8902, Port 6, at a depth of 23.7 m (78 ft) on February 3, 2004. This is approaching the highest concentration measured in vadose zone monitoring wells, which was 4,864 ppmv in nearby Well 9302, Port 6, at a depth of 23.5 m (77 ft) in January 1995. The highest levels of CCl₄ are located in the central portion of the SDA between Pits 4, 5, 6, and 10 and decrease with distance away from this area. Concentrations in the wells farthest from the SDA, OCVZ-11, and OCVZ-13 are less than 1 ppmv.

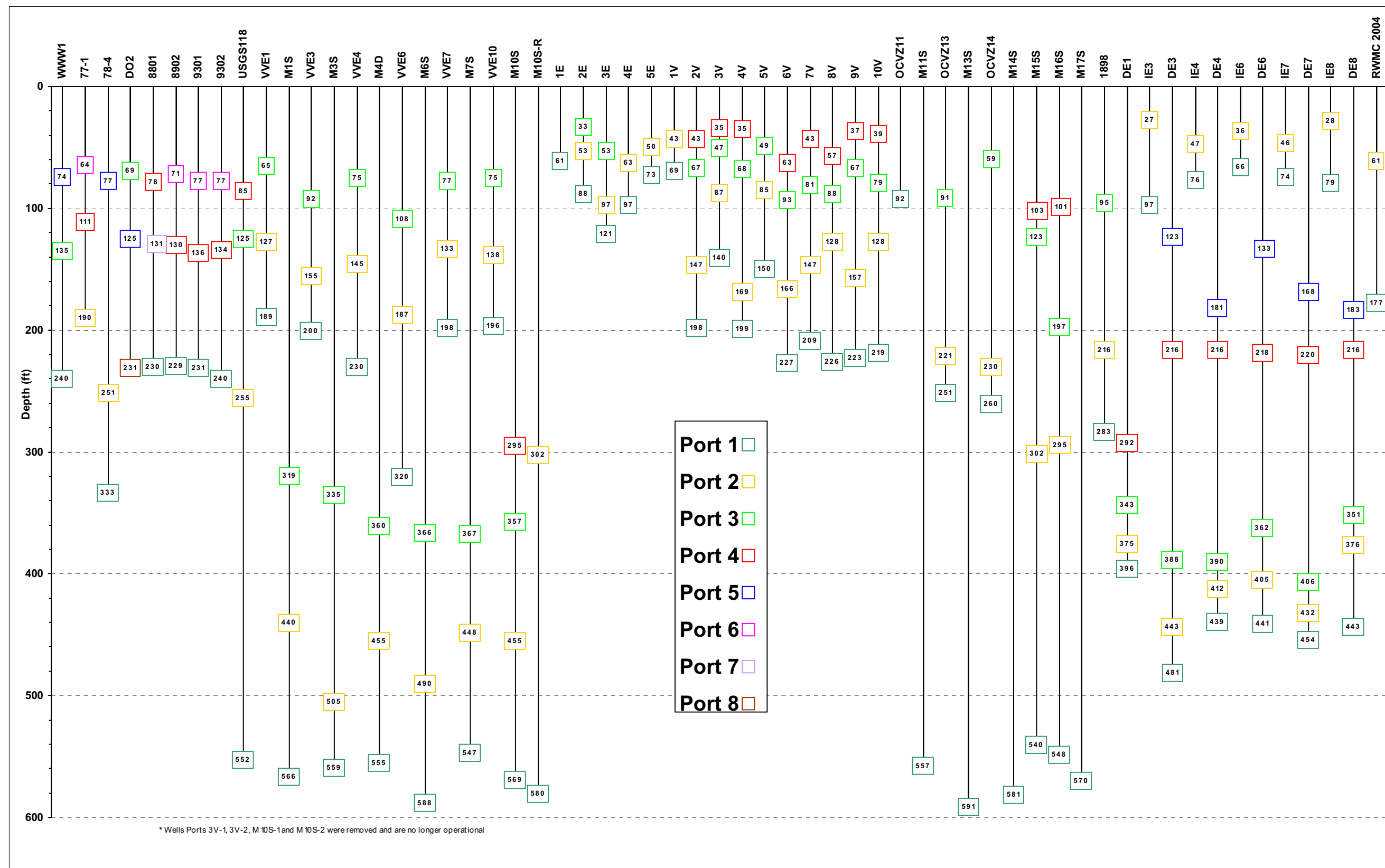


Figure 4-2b. Depth of the sampling ports in wells in the vicinity of the Radioactive Waste Management Complex.

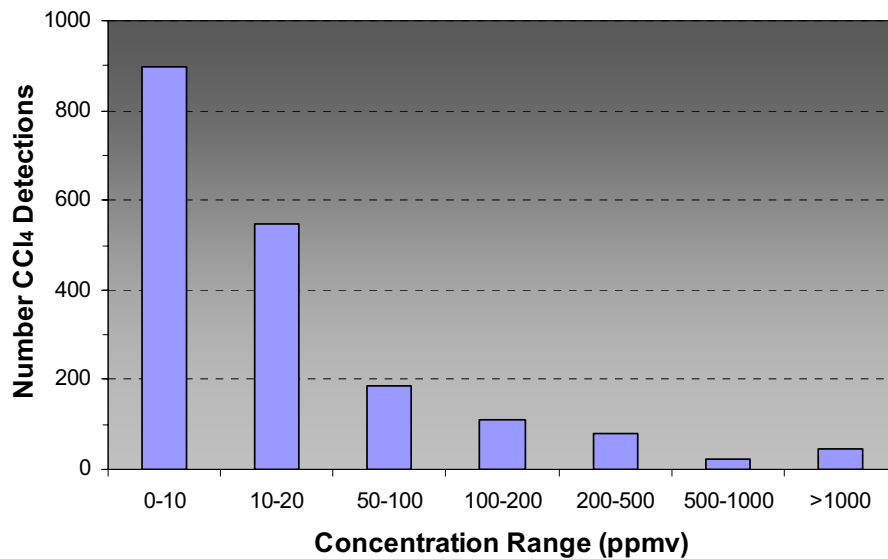


Figure 4-3. Histogram showing the detection frequencies of carbon tetrachloride in vadose zone soil gas samples collected during FY 2004 in the vicinity of the Radioactive Waste Management Complex.

Vertically, the CCl₄ soil-gas contamination extends from land surface down to the water table. Currently, in the center of the SDA, the CCl₄ concentrations can be 1,000 ppmv or higher above the B-C interbed. Concentrations then decrease sharply across the B-C interbed down to a few hundred ppmv. Below the C-D interbed, concentrations are generally less than 50 ppmv. However, it appears that when the VVET systems are extracting from the deep extraction wells, the maximum concentrations are reduced to approximately 20 ppmv or less.

Overall, the organic vapor concentrations at most locations are much less now than before full-time operation of the OCVZ VVET system began in January 1996. Figures 4-4 and 4-5 show the soil-gas concentrations at two wells (8801 and 9301) near vapor extraction Well 8901D. In 1993, a treatability study was performed and soil-gas extraction from Well 8901D was performed for approximately 3 months. This event had little lasting impact on the concentration levels. Before 1996, the CCl₄ concentration at about 23.5 m (77 ft) deep (above the B-C interbed) was approximately 3,000 ppmv in these two wells. However, after full-time extraction began in January 1996, the concentration dropped to about 1,000 ppmv. Near the 40-m (130-ft) depth below the B-C interbed, the concentration dropped from about 600 ppmv before vapor vacuum extraction operations to 100 ppmv after operations. Concentrations in the deeper ports, around 70 m (230 ft), appear to be unchanged by operations. In Well 9V (see Figure 4-6), the initial drop in concentration was not so dramatic, probably because it is located farther from an extraction well; however, the decrease has been steady. Even the deep gas port at 68 m (223 ft) shows a clear decline in concentrations.

In FY 2004, vadose zone soil-gas concentrations at several locations showed an overall increase over FY 2003 levels. The increase in FY 2004 is the result of VVET Units A and B being shut down for an extended period of time before being replaced with Units E and F, respectively. Unit B ceased operation in February 2003, and replacement Unit F was started briefly, nearly a year later, in January 2004, and did not begin full-scale operations until March 2004. Unit A was shut down in September 2003, and replacement Unit E was started in April 2004. During the time Unit B and especially Unit A were down, the concentrations in nearby monitoring wells (e.g., 8801, DO2, 9301, 9302, IE7, IE8, 2E) increased dramatically. Soon after starting Unit E, however, the concentrations in those wells decreased just as dramatically. This can be seen in Figures 4-4, 4-5, and to a lesser degree, in Figure 4-6.

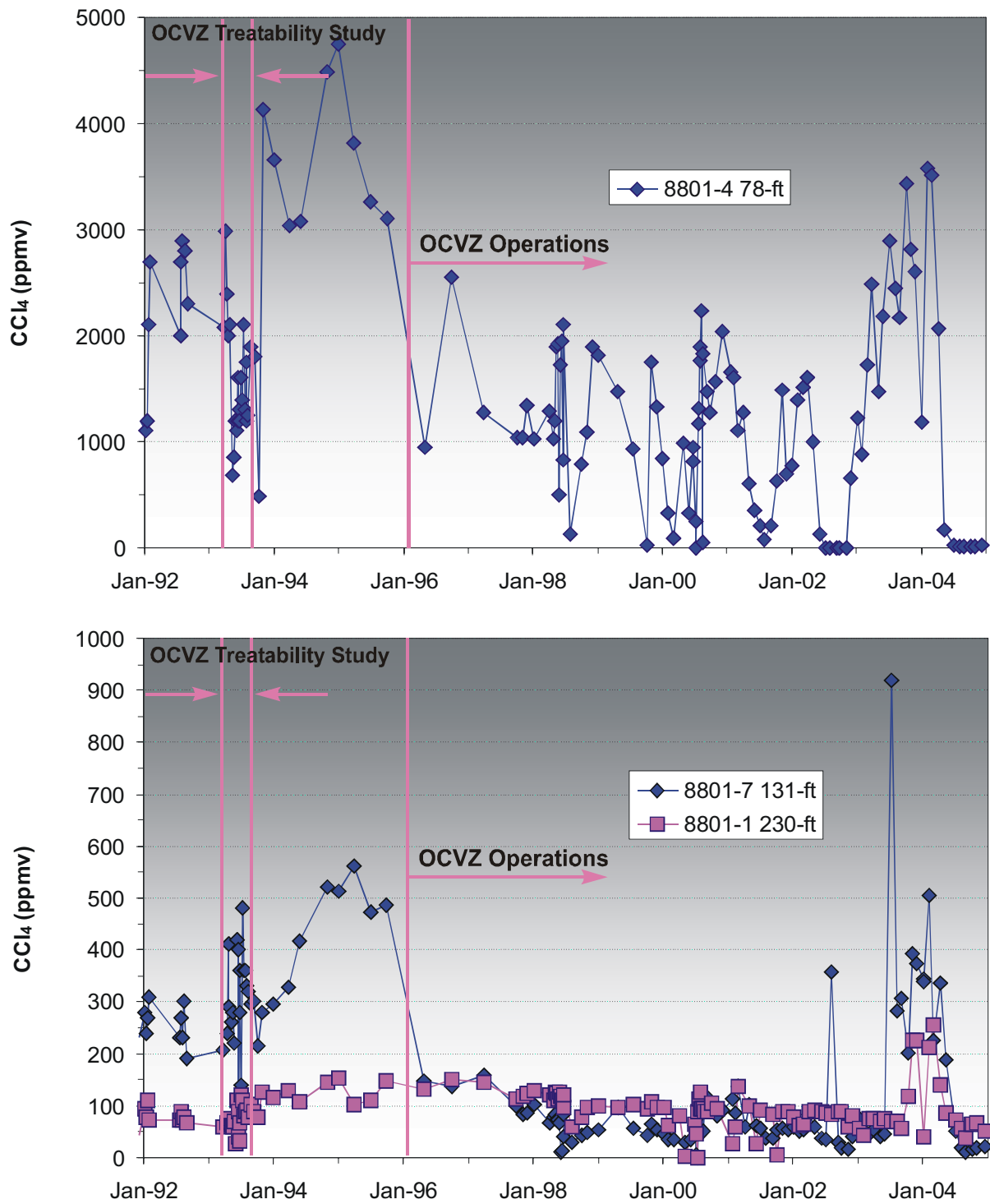


Figure 4-4. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 8801.

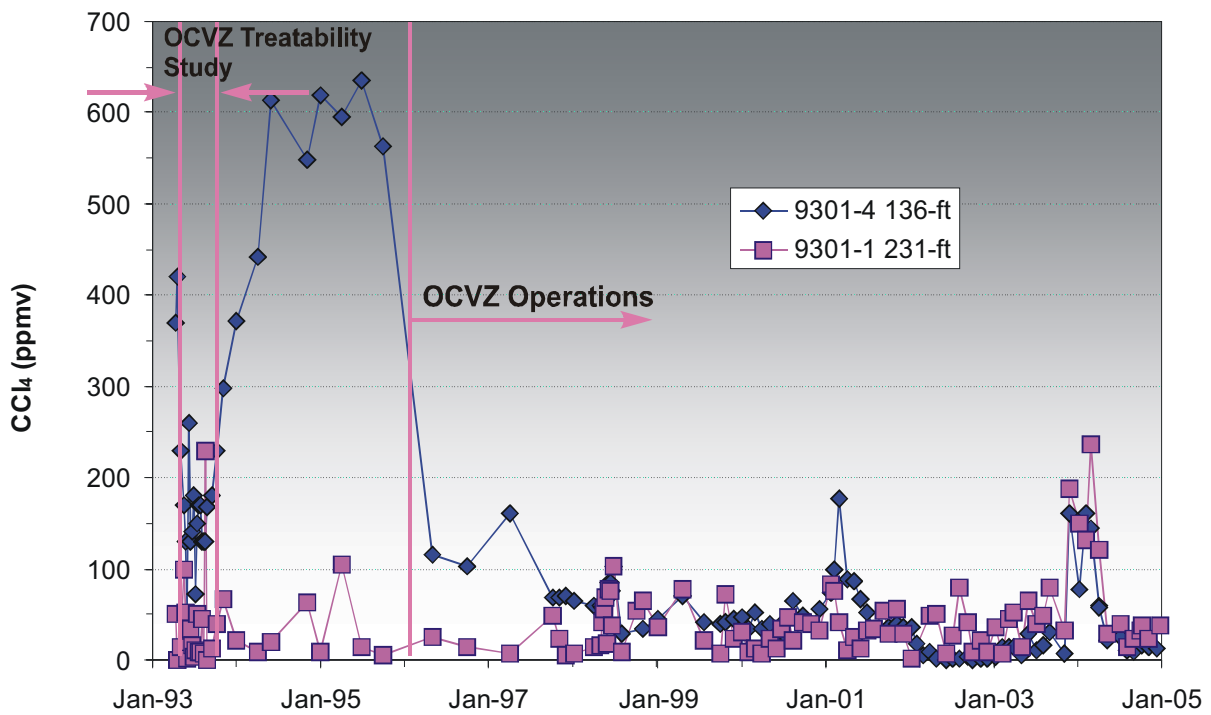
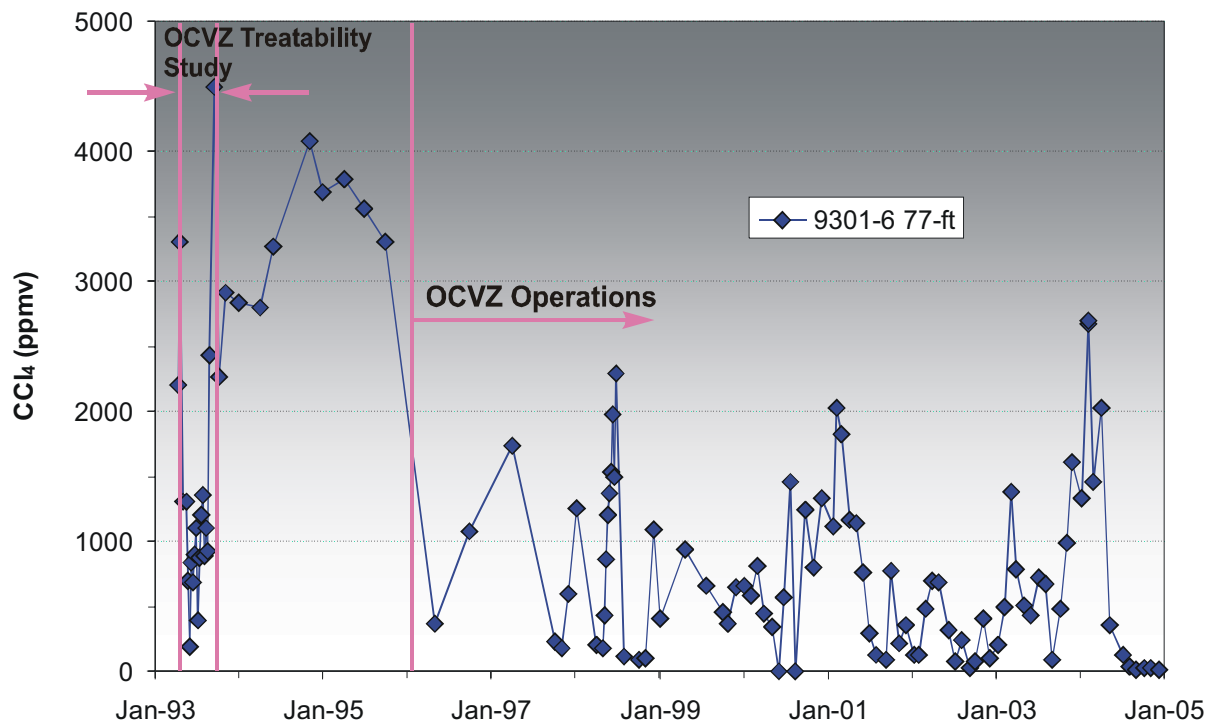


Figure 4-5. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9301.

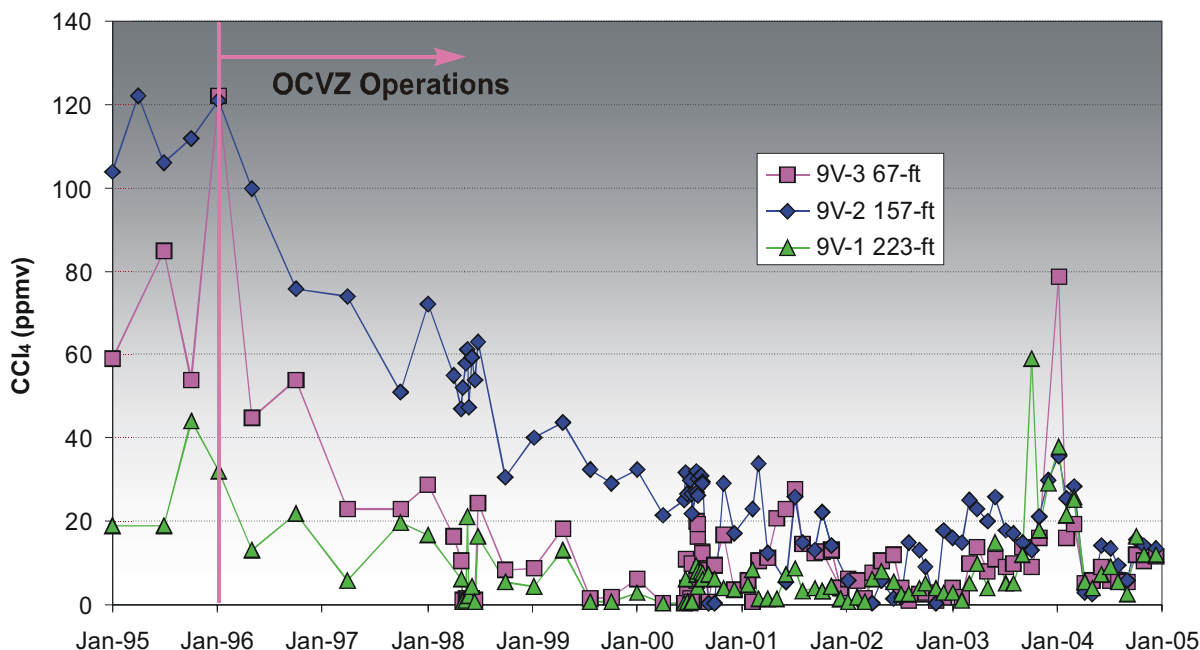


Figure 4-6. Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9V.

4.1.3 Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells and analyzed for CCl₄. Twenty-nine of those 47 samples (i.e., 62 percent) had detections above the quantitation limit of 1 µg/L. Of those 29 detections, two (i.e., 7 percent) exceeded the primary drinking water MCL of 5 µg/L. This is down from 21 percent (seven out of 33) in FY 2003. Samples collected by WAG 7 were collected in December 2003, January 2004, and April/May 2004 from monitoring Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127. No sampling was conducted in the fourth quarter of FY 2004 because of a switch to semiannual sampling, which began after the third quarter sampling was complete. The WAG 7 aquifer sampling results above the quantitation limit are Summarized in Table 4-2.

The USGS collected 19 of the 68 aquifer samples from six aquifer wells in the vicinity of the RWMC. Fifteen of the 19 samples (i.e., 79 percent) had detections greater than or equal to the minimum reporting level of 0.2 µg/L. Of the 15 detections, eleven (i.e., 73 percent) met or exceeded the primary drinking water MCL of 5 µg/L. This is up from 44 percent in FY 2003. All eleven samples that exceeded the MCL were taken from the RWMC Production Well. Only the sample taken in March 2004 did not exceed the MCL. Monthly samples were collected by the USGS from the RWMC Production Well. Samples were collected in October 2003 from Wells USGS-87, USGS-89, and USGS-120. Samples were collected in April 2004 from wells USGS-87, USGS-89, USGS-117, and USGS-119. The USGS sample results greater than or equal to the minimum reporting level are also summarized in Table 4-2. Volatile organic compound data from the USGS could only be obtained through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Table 4-2. Carbon tetrachloride results above quantitation limit (Waste Area Group 7 results) or minimum reporting level in the aquifer (USGS results) in the vicinity of the Radioactive Waste Management Complex.

Well	Sample Date	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)
Waste Area Group 7 Monitoring Results			
M14S	12/01/03	0.95 ^a	1.0
M16S	12/01/03	4.3	1.0
M6S	12/01/03	2.1	1.0
M7S	12/01/03	4.5	1.0
A11A31	12/02/03	4.5	1.0
M3S	12/02/03	2.1	1.0
OW2	12/02/03	0.46 ^a	1.0
OW2	12/02/03	0.47 ^a	1.0
M15S	12/03/03	1.9	1.0
M17S	12/03/03	1.8	1.0
A11A31	01/20/04	4.9	1.0
M6S	01/20/04	2	1.0
M7S	01/20/04	5.2 ^b	1.0
M16S	01/21/04	4.4	1.0
M17S	01/21/04	1.7	1.0
M14S	01/26/04	0.86 ^a	1.0
OW2	01/26/04	0.46 ^a	1.0
OW2	01/26/04	0.41 ^a	1.0
M15S	01/27/04	1.8	1.0
M3S	01/27/04	2.2	1.0
A11A31	04/26/04	3.4	1.0
M14S	04/26/04	0.9 ^a	1.0
M3S	04/27/04	2.5	1.0
M6S	05/03/04	2.8	1.0
OW2	05/03/04	0.81 ^a	1.0
M15S	05/04/04	1.9	1.0
M16S	05/04/04	4.2	1.0
M16S	05/04/04	4.3	1.0
M7S	05/05/04	6.1 ^b	1.0
United States Geological Survey Monitoring Results			
RWMC Production	10/09/03	5.4 ^b	0.2
	11/13/03	6 ^b	0.2
	12/18/03	6.8 ^b	0.2
	01/15/04	6.3 ^b	0.2
	01/15/04	6.3 ^b	0.2
	02/12/04	6.2 ^b	0.2
	03/11/04	4.9	0.2
	04/08/04	6.2 ^b	0.2
	05/12/04	6 ^b	0.2

Table 4-2. (continued).

Well	Sample Date	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)
RWMC Production	06/10/04	5.4 ^b	0.2
	07/08/04	5.5 ^b	0.2
	08/12/04	6 ^b	0.2
USGS-087	10/09/03	3.3	0.2
USGS-087	04/08/04	3.3	0.2
USGS-089	10/02/03	<0.2	0.2
USGS-089	04/13/04	<0.2	0.2
USGS-117	04/07/04	<0.2	0.2
USGS-119	04/07/04	<0.2	0.2
USGS-120	10/09/03	3.0	0.2

a. Concentrations with a “J” subscript were positively identified in the sample and assigned a “J” data qualifier flag. The qualifier flag was assigned because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities.

b. **Red bold font** indicates sample concentrations that exceed the MCL.

MCL = maximum contaminant level

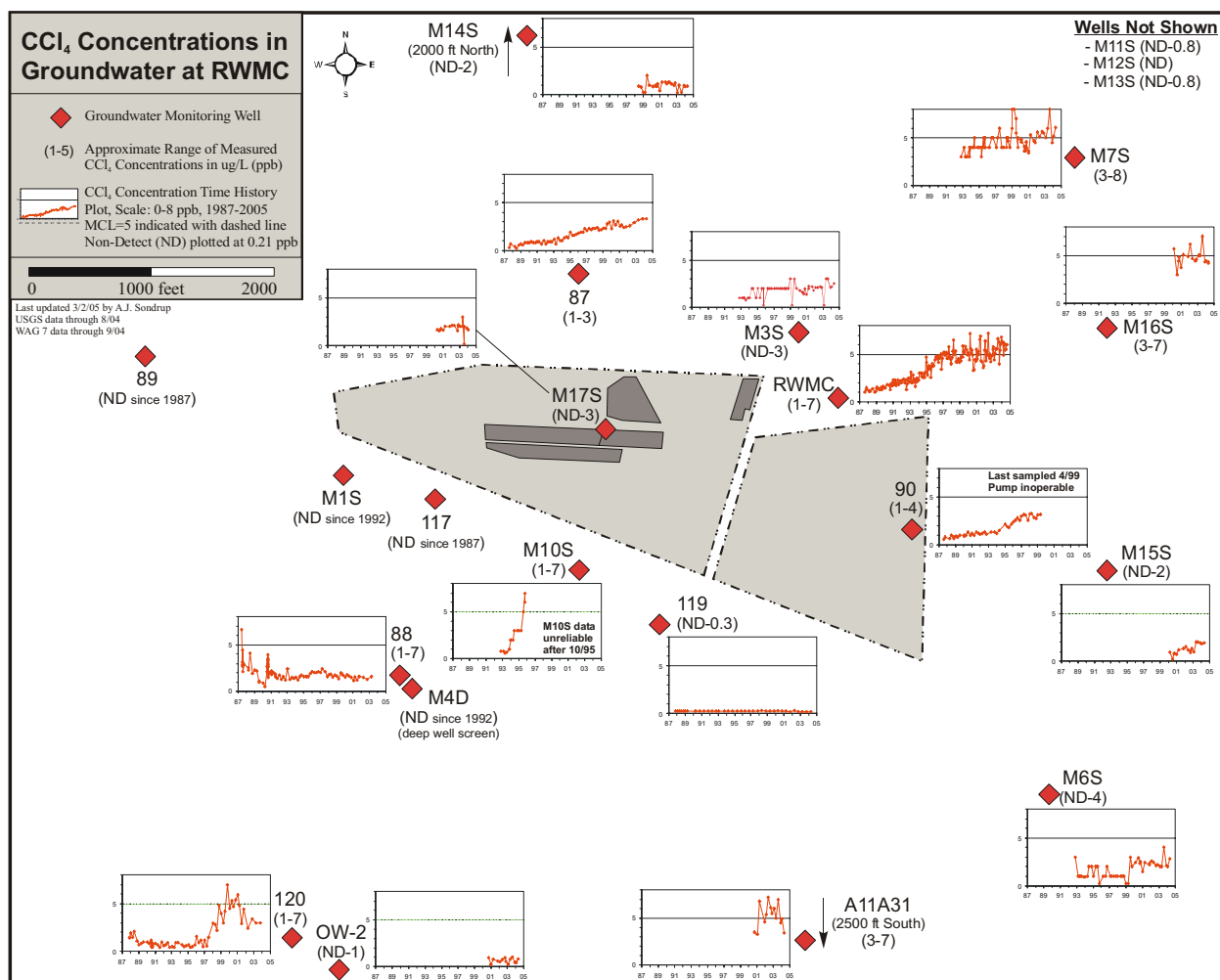
When FY 2004 WAG 7 and USGS results are combined, CCl₄ was consistently detected in 12 of 21 aquifer-monitoring wells. Concentrations in these wells varied from 0.2–6.8 µg/L, with two wells (M7S and RWMC Production) exceeding the MCL. This is down from four wells in FY 2003. The nine wells where CCl₄ was not detected are M1S, M4D, M11S, M12S, M13S, USGS-89, USGS-117, USGS-119, and USGS-127. Four of these wells (M11S, M12S, M13S, and USGS-127) are more than 2.4 km (1.5 mi) from the SDA.

Figure 4-7 shows the concentration time history of CCl₄ in RWMC-vicinity wells. Although concentrations have increased over the past several years, data from the last few years indicate a flat trend in most wells. Wells A11A31 and USGS-120 show a decreasing trend over the past few years.

4.1.4 Summary of Carbon Tetrachloride

Carbon tetrachloride was detected in FY 2004 in waste zone soil gas, vadose zone soil gas, and in the aquifer in and around the RWMC. None of the perched water samples obtained in FY 2004 were analyzed for organics due to limited sample volumes. The highest soil-gas concentration was 79,600 ppmv, measured in the waste zone soil gas. The maximum soil-gas concentration outside the waste zone was 4,030 ppmv measured in Well 8902, Port 6, at 24 m (78 ft) bls. Soil-gas concentrations at many locations were higher than usual in FY 2004 due to the shutdown of two VVET units for a majority of the year. Nevertheless, CCl₄ concentrations in vadose zone soil gas are appreciably lower since the OCVZ Project began operation of a VVET system.

In FY 2004, low levels of CCl₄ were consistently detected in aquifer-monitoring wells in and around the RWMC. The maximum concentration was 6.8 µg/L measured in the RWMC Production Well. Measured concentrations exceeded the MCL of 5 µg/L in only two wells (M7S and the RWMC Production Well), down from four wells in FY 2003. Although concentrations in some wells have increased over the past several years, the data indicate a relatively flat and perhaps slightly declining trend in many wells during the past few years. No wells exhibited an obvious increasing trend over the past few years, but Wells USGS-120 and A11A31 show a decreasing trend.



Tetrachloroethene was detected in all of the probes that yielded a vapor sample in FY 2004. Table 4-1 contains the PCE results as well as results for the other gases for which analyses were performed. Tetrachloroethene concentrations in the Depleted Uranium Focus Area (west end of Pit 10) were very similar to those measured in FY 2003. Concentrations at locations DU-08 and DU-10 were approximately 1,000–2,000 ppmv. In the Series 743 Focus Area, however, FY 2004 concentrations were much greater than FY 2003 levels. Tetrachloroethene concentrations at locations 743-03, 743-08, and 743-18 were approximately 1,000–3,000 ppmv in FY 2004, while in FY 2003, the maximum concentration was 66 ppmv. The maximum PCE concentration measured was 3,680 ppmv at Probe 743-08-VP1 at a depth of 6.4 m (21 ft) bls, in February 2004. This is greater than the estimated equilibrium vapor concentration of CCl₄ in Series 743 sludge (750 ppmv at 10°C). However, the estimated equilibrium vapor concentration for PCE is small, because PCE is estimated to be a small fraction of the VOC components in Series 743 sludge. Nevertheless, results indicate that Series 743 sludge continues to be a source of PCE and other VOCs.

Tetrachloroethene concentrations at all three vapor probe locations in the 743 Focus Area show a similar trend over the quarterly sampling rounds in FY 2004. The first quarter sample results were relatively low, consistent with the previous year. In the second quarter, however, the results increased dramatically. Third and fourth quarter results were much less than the second quarter, but greater than the first quarter results. A likely possibility for this is that, after the first quarter samples were taken, three soil moisture probes (743-03-M2, 743-18-M2, and 743-18-M3) were installed in the 743 Focus Area near the vapor probes. Relatively “fresh” sludge could have been disturbed by installation of the probe releasing VOCs into the subsurface.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities.

4.2.2 Vadose Zone

4.2.2.1 Perched Water and Lysimeter. Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

U.S. Geological Survey personnel attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained from Well USGS-92 in May 2004, but it was not analyzed for organics. Tetrachloroethene has been detected consistently in Well USGS-92 since 1987. The maximum concentration measured was 180 µg/L on February 29, 1996, and the minimum was 23 µg/L on March 30, 1999. Since the OCVZ Project began operating the VVET system, PCE concentrations in perched water from Well USGS-92 have declined.

4.2.2.2 Soil Gas. Tetrachloroethene has been detected consistently in soil gas at the RWMC for several years, but at much lower concentrations than CCl₄. Before FY 2002, the historic maximum PCE concentration was 135 ppmv in Well 8902, Port 4, at a depth of 39 m (130 ft) on January 4, 1996. This was immediately prior to the VVET system beginning full-scale operations. Since April 1998, the PCE concentrations in Well 8902, Port 4, have been less than 10 ppmv.

Since June 2002, there have been several anomalously high PCE measurements, which occurred almost exclusively at Wells 77-1 and 78-4. Validity of these results is highly questionable for two reasons. First, the wells are more than 305 m (1,000 ft) from an organic sludge disposal area. Second, just before the dramatic increase in concentration at these wells, sulfur hexafluoride (SF₆) gas was used for a gas tracer test in these two wells. It is very likely that the SF₆ interferes with the PCE filter on the Brüel

and Kjær gas analyzer. Since the tracer test, the number of anomalous readings has decreased, but they still persist. The maximum PCE concentration in soil gas in FY 2004 was 107 ppmv in Well 77-1, Port 4, at a depth of 32 m (104 ft) on October 7, 2003. The last sample analyzed in FY 2004 from this same port was 47 ppmv measured on September 1, 2004. Because PCE concentrations at this location before the SF₆ tracer test were less than 20, it appears that the SF₆ interference still persists, but the PCE concentrations are decreasing.

If the questionable high concentrations at Wells 77-1 and 78-4 are not considered, the maximum PCE concentration measured in FY 2004 was 67 ppmv at Well 2E, Port 1, at a depth of 27 m (88 ft) on March 1, 2004. Only one other measurement was above 50 ppmv during FY 2004, and that was at Well IE6, Port 2. The majority of the PCE results were quite low. For example, of all the PCE vadose zone soil-gas results in FY 2004, more than 90 percent were less than 5 ppmv. A histogram displays this in Figure 4-8.

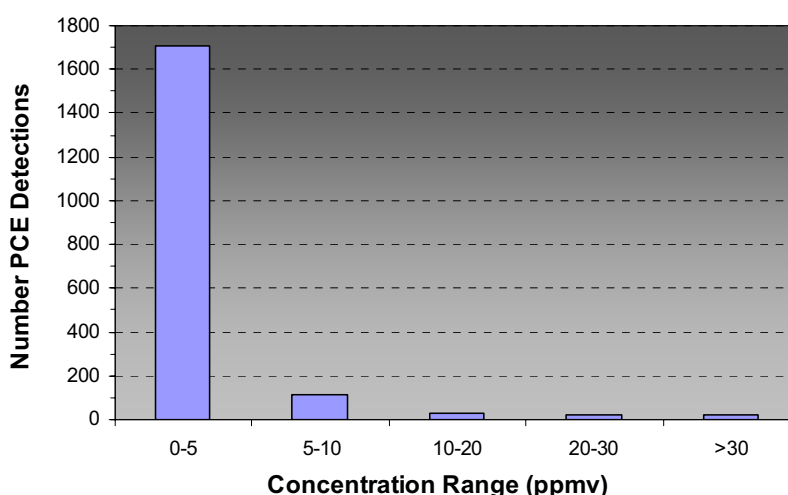


Figure 4-8. Histogram showing the detection frequencies of tetrachloroethene in vadose zone soil gas samples collected during FY 2004 in the vicinity of the Radioactive Waste Management Complex.

4.2.3 Snake River Plain Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and were analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells (i.e., Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). None of the 62 samples had PCE detections above the quantitation limit of 1 µg/L. Two of the samples, both collected from Well M7S, had estimated concentrations (J flag) of 0.34 and 0.46 µg/L.

Nineteen of the 68 aquifer samples were collected by USGS personnel from six aquifer wells in the vicinity of the RWMC. Samples were collected monthly from the RWMC Production Well; in October 2003 from Wells USGS-87, USGS-89, and USGS-120; and then in April 2004 from Wells USGS-87, USGS-89, USGS-117 and USGS-119. Fifteen of the 19 samples had PCE detections above the USGS minimum reporting level of 0.1 µg/L. The maximum concentration measured was 0.3 µg/L in the RWMC Production Well. This value was measured four times in the RWMC Production Well in FY 2004 compared to only once in FY 2003, and VOC data from the USGS could only be obtained through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Positive detections of PCE in SDA-vicinity aquifer wells are infrequent. The historical maximum PCE concentration measured was 0.4 µg/L in Well M7S on five different occasions from 1993 to 1996. This is far below the MCL of 5 µg/L.

4.2.4 Summary of Tetrachloroethene

Tetrachloroethene was detected in FY 2004 in waste zone soil gas, vadose zone soil gas, and in the aquifer in the vicinity of the RWMC. None of the perched water samples obtained in FY 2004 were analyzed for organics due to limited sample volumes. The maximum soil-gas concentration was 2,274 ppmv measured in the waste zone. Excluding a few questionable high measurements, likely due to interference from a tracer gas (SF₆) used in 2002, the maximum PCE concentration in vadose zone soil gas was 67 ppmv. Over 90 percent of the PCE soil gas results were less than 5 ppmv.

Positive detections of PCE in SDA-vicinity aquifer wells are infrequent. The maximum aquifer concentration measured in FY 2004 was 0.3 µg/L from the RWMC Production Well. A concentration of 0.46 µg/L was estimated (J-flag) for Well M7S, but this is below the quantitation limit of 1 µg/L. Aquifer results are consistent with the FY 2003 results, because there does not appear to be an increasing or decreasing trend.

4.3 Methylene Chloride

Approximately 1.4E+04 kg of methylene chloride were buried in the SDA (Holdren et al. 2002). Information about methylene chloride disposal is scant compared to that for other, more prevalent VOCs like CCl₄. It should be noted that methylene chloride is a degradation byproduct of CCl₄; thus, considering the large mass of CCl₄ buried in the SDA, detections of methylene chloride in samples might not necessarily be related to the original inventory buried in the SDA.

4.3.1 Waste Zone

The INNOVA instrument used to analyze soil-vapor probe samples from the waste zone is not set up to detect methylene chloride. Therefore, only duplicate gas samples from the soil-vapor probes that are sent to a laboratory are analyzed for methylene chloride. In FY 2004, methylene chloride was identified above the method detection limit in four of 11 samples from six different probes, yet one of those detections was below the practical quantitation limit (J-flag). The maximum concentration was 980 ppmv measured on September 27, 2004, at Probe 743-08-VP1 at a depth of 6.4 m (21 ft). The maximum concentration in FY 2003 was 710 ppmv at the same probe location. The methylene chloride results from vapor probe sampling are shown in Table 4-3.

Table 4-3. Fiscal Year 2004 methylene chloride vapor concentration results from soil-vapor probes in the Subsurface Disposal Area.

Probe	Port Depth (ft)	Date Sampled	Sample No.	Methylene Chloride (ppmv) ^a
743-08-VP1	21	5/27/04	IPV34201HU	U
		9/27/04	IPV358013A	980
		9/28/04	IPV358013ADL	U
743-08-VP2	14	2/17/04	IPV32701VT	U
		5/27/04	IPV34301HU	U
743-18-VP4	15	11/11/03	IPV31501VT	9.8 ^{b J}

Table 4-3. (continued).

Probe	Port Depth (ft)	Date Sampled	Sample No.	Methylene Chloride (ppmv) ^a
DU-08-VP2	16	2/17/04	IPV31601VT	450
		5/26/04	IPV33201HU	U
DU-10-VP2	11	5/26/04	IPV33401HU	U
		9/27/04	IPV350013A	U
DU-14-VP2	12	11/10/03	IPV30501VT	210

a. U = undetected

b. Concentrations with a “J” subscript were positively identified in the sample and assigned a “J” data qualifier flag. The qualifier flag was assigned, because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities. As a result, J-flag data were not considered for the maximum concentration level.

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities.

4.3.2 Vadose Zone

4.3.2.1 Perched Water and Lysimeter. Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 because of limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. From 1997 until 2003, methylene chloride had been consistently detected in Well USGS-92. Before that, it was analyzed for but not detected above the minimum reporting level of 0.2 µg/L. The maximum methylene chloride concentration in perched water from Well USGS-92 was 22.4 µg/L on April 17, 2001. The last perched water sample analyzed from Well USGS-92 was collected in April 2003 and contained less than 0.2 µg/L methylene chloride.

4.3.2.2 Soil Gas. None of the soil gas samples collected from the vadose zone vapor sampling ports since FY 2001 have been analyzed for methylene chloride. However, of the hundreds of samples collected before FY 2002 and analyzed for methylene chloride, only five returned positive detections, and the concentrations were relatively low compared to other VOCs (e.g., CCl₄, chloroform, 1,1,1-trichloroethane, trichloroethene [TCE], and PCE).

4.3.3 Snake River Plain Aquifer

Sixty-eight aquifer samples were collected in FY 2004 from 21 monitoring wells in the vicinity of the RWMC and analyzed for VOCs. Forty-seven of the samples were collected by WAG 7 personnel from 15 monitoring wells (i.e., Wells AllA31, M1S, M3S, M4D, M6S, M7S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW2, and USGS-127). Only one of the 62 samples had a detection of methylene chloride above the quantitation limit of 1 µg/L.

Personnel from the USGS collected 19 of the 68 aquifer samples from six aquifer wells in the vicinity of the RWMC. Samples were collected by the USGS monthly from the RWMC Production Well; in October 2003 from Wells USGS-87, USGS-89, and USGS-120; and then in April 2004 from Wells USGS-87, USGS-89, USGS-117, and USGS-119. None of the 19 samples had detection greater

than or equal to the USGS minimum reporting level of 0.2 µg/L. It should be mentioned that VOC data from the USGS could be obtained only through August 2004. The September sample from the RWMC Production Well was not included in this discussion.

Positive detections of methylene chloride in SDA-vicinity aquifer wells are infrequent. The historical maximum methylene chloride concentration measurement was 8 µg/L in Well M10S, collected on July 22, 1996, which is greater than the MCL of 5 µg/L. However, five of the total seven detections historically were during the same sampling round (July 1996), which raises the question as to whether the samples were cross-contaminated before or during analysis. Methylene chloride was reported at 2.8 µg/L in Well M1S in November 2002, but it was also detected in the associated blank. Except for this, methylene chloride has not been detected in any aquifer wells since October 1997.

4.3.4 Summary of Methylene Chloride

Methylene chloride was detected in four of 11 soil-vapor samples taken from vapor probes in the waste zone. The maximum concentration was 980 ppmv. No lysimeter, perched water, or vadose zone soil-gas samples were analyzed for methylene chloride in FY 2004. In all of the 68 aquifer samples collected, methylene chloride was not detected above the quantitation limit of 1 µg/L (WAG 7 wells) or the minimum reporting level of 0.2 µg/L (USGS wells).

4.4 Other Organic Contaminants

Series 743 waste is known to contain other organic compounds (e.g., 1,1,1-trichloroethane and PCE). These organic compounds have been detected in virtually all media in an around the SDA. The estimated mass of 1,1,1-trichloroethane and PCE in Series 743 sludge is 8.19E+04 kg and 8.92E+04 kg, respectively (Varvel 2005). Chloroform detections are also prevalent at the SDA, but records indicate very little chloroform was buried. Most of the chloroform is believed to be a degradation product of CCl₄. Disposal amounts of other organic compounds are very small compared to the amounts in Series 743 sludge.

4.4.1 Waste Zone

Besides CCl₄ and PCE, gas samples collected from vapor probes placed in the waste in Pits 4 and 10 were analyzed for chloroform, 1,1,1-trichloroethane (1,1,1-TCA), and TCE using the INNOVA Model 1314 photoacoustic multigas analyzer. Some of the field duplicate samples also were analyzed using standard laboratory GC/MS as an accuracy check on the INNOVA results. The duplicate samples were analyzed for several other VOCs.

Chloroform, 1,1,1-TCA, and TCE were detected in all of the waste-zone vapor probes that yielded a vapor sample. Other VOCs detected in the samples analyzed by GC/MS include chloromethane, 1,1-dichloroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113). Table 4-4 shows the maximum results for each of the other organics identified in the vapor probes samples.

Table 4-4. Maximum concentrations of other organics detected in soil gas from waste zone vapor probes.

Organic Compound	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Trichloroethene	9/28/04	743-08-VP1	21	14,000
1,1,1-Trichloroethane	11/10/03	DU-08-VP2	16	3,810
Chloroform	9/28/04	743-08-VP1	21	18,000

Table 4-4. (continued).

Organic Compound	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Chloromethane	9/27/04	743-08-VP1	21	1,400
Freon-113 ^a	9/27/04	743-08-VP1	21	200
1,1-Dichloroethane	9/27/04	DU-10-VP2	11	45

a. Freon-113 = 1,1,2-trichloro-1,2,2-trifluoroethane

Waste zone soil-moisture samples were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities.

4.4.2 Vadose Zone

4.4.2.1 Perched Water and Lysimeter. Vadose zone soil-moisture samples collected by WAG 7 were not analyzed for VOCs in FY 2004 due to limited sample volumes and analytical priorities. Samples collected by WAG 7 have not been analyzed for VOCs since September 2000.

Personnel from the USGS attempted to collect a perched water sample from Well USGS-92 in April 2004, but there was insufficient water for a sample. A perched water sample was obtained in May 2004 from Well USGS-92, but it was not analyzed for organics. In general, TCE, 1,1,1-TCA, and chloroform are historically the only other organics consistently detected in perched water.

4.4.2.2 Soil Gas. Chloroform, 1,1,1-TCA, and TCE are the only other VOCs for which analysis is performed on vadose zone soil-gas samples routinely collected at the SDA. All three compounds are ubiquitous in the vicinity of the RWMC, but at much lower concentrations than CCl₄. Nevertheless, the trends are very similar to the CCl₄ concentrations. Figure 4-9 contains histograms showing the detection frequencies for chloroform, 1,1,1-TCA, and TCE in vadose zone soil-gas samples collected during FY 2004. The majority of the results are less than 5 ppmv for all three compounds.

The maximum concentrations of chloroform, 1,1,1-TCA and TCE detected in FY 2004 both inside and outside of the SDA are shown in Table 4-5.

Table 4-5. Maximum concentrations of trichloroethene, 1,1,1-trichloroethane, and chloroform detected in vadose zone soil gas inside and outside of the Subsurface Disposal Area in Fiscal Year 2003.

Organic Compound	Inside or Outside the Subsurface Disposal Area	Sample Date	Well Port	Depth (ft)	Concentration (ppmv)
Chloroform	Inside	3/1/04	8801-4	78	1,030
1,1,1-Trichloroethane	Inside	3/1/04	2E-1	88	370
Trichloroethene	Inside	12/1/03	8902-6	71	523
Chloroform	Outside	8/4/04	2V-4	43	35
1,1,1-Trichloroethane	Outside	5/3/04	77-1-4	111	10
Trichloroethene	Outside	12/1/03	2V-1	198	23

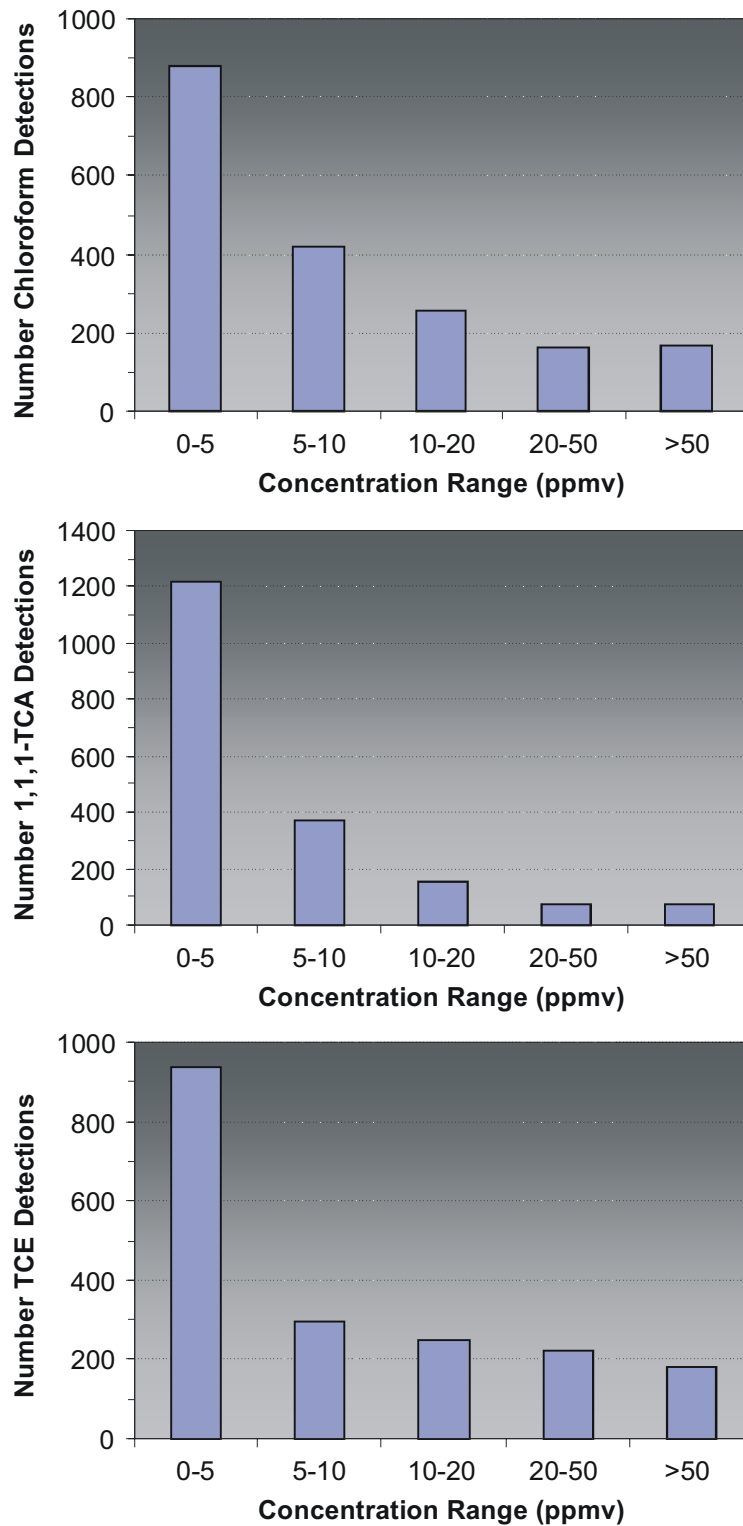


Figure 4-9. Histograms showing the detection frequencies for chloroform, 1,1,1-trichloroethane, and trichloroethene in vadose zone soil gas samples collected during Fiscal Year 2004 in the vicinity of the Radioactive Waste Management Complex.

4.4.3 Snake River Plain Aquifer

In addition to CCl₄, PCE, and methylene chloride, RWMC aquifer samples in FY 2004 were analyzed for other VOCs and most were nondetections. Chloroform, TCE, 1,1,1-TCA, and toluene were the only compounds detected at concentrations above the quantitation limit (WAG 7 wells) or minimum reporting levels (USGS wells). All compounds were below the respective MCLs. Table 4-6 contains the results for all detections of other organics from aquifer samples.

Table 4-6. Concentration of other volatile organic compounds detected in the aquifer in the vicinity of the Radioactive Waste Management Complex in Fiscal Year 2004.

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Waste Area Group 7 Monitoring Results					
Chloroform	12/1/03	M7S	0.61 _J ^a	1.0	100
	12/1/03	M16S	0.51 _J ^a	1.0	100
	12/2/03	A11A31	1	1.0	100
	12/3/03	M15S	0.39 _J ^a	1.0	100
	1/20/04	M7S	0.5 _J ^a	1.0	100
	1/20/04	A11A31	0.83 _J ^a	1.0	100
	1/21/04	M16S	0.42 _J ^a	1.0	100
	4/26/04	A11A31	0.9 _J ^a	1.0	100
	5/3/04	M6S	0.41 _J ^a	1.0	100
	5/4/04	M15S	0.38 _J ^a	1.0	100
	5/4/04	M16S	0.49 _J ^a	1.0	100
	5/4/04	M16S	0.53 _J ^a	1.0	100
	5/5/04	M7S	0.73 _J ^a	1.0	100
Trichloroethene	12/1/03	M6S	0.76 _J ^a	1.0	5
	12/1/03	M7S	1.80	1.0	5
	12/1/03	M16S	1.80	1.0	5
	12/2/03	M3S	0.54 _J ^a	1.0	5
	12/2/03	A11A31	2.10	1.0	5
	12/3/03	M17S	0.42 _J ^a	1.0	5
	12/3/03	M15S	0.82 _J ^a	1.0	5
	1/20/04	M6S	0.47 _J ^a	1.0	5
	1/20/04	M7S	1.8	1.0	5
	1/20/04	A11A31	2	1.0	5
	1/21/04	M16S	1.7	1.0	5
	1/27/04	M3S	0.53 _J ^a	1.0	5
	1/27/04	M15S	0.69 _J ^a	1.0	5
	4/26/04	A11A31	1.7	1.0	5
	4/27/04	M3S	0.64 _J ^a	1.0	5
	5/3/04	M6S	0.95 _J ^a	1.0	5
	5/4/04	M15S	0.9 _J ^a	1.0	5
	5/4/04	M16S	1.9	1.0	5

Table 4-6. (continued).

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Trichloroethene	5/4/04	M16S	1.8	1.0	5
	5/5/04	M7S	2.5	1.0	5
1,1,1-TCA	12/1/03	M7S	0.45 _J ^a	1.0	200
	12/1/03	M16S	0.46 _J ^a	1.0	200
	12/2/03	A11A31	0.37 _J ^a	1.0	200
	1/20/04	M7S	0.49 _J ^a	1.0	200
	5/4/04	M16S	0.39 _J ^a	1.0	200
	5/4/04	M16S	0.43 _J ^a	1.0	200
	5/5/04	M7S	0.59 _J ^a	1.0	200
Toluene	12/1/03	M7S	3.1	1.0	1,000
	12/2/03	A11A31	6.3	1.0	1,000
	12/3/03	M15S	24 ^b	1.0	1,000
	1/20/04	M7S	3.1	1.0	1,000
	1/27/04	M15S	13	1.0	1,000
	4/26/04	A11A31	0.63 _J ^a	1.0	1,000
	5/4/04	M15S	4	1.0	1,000
	5/5/04	M7S	3	1.0	1,000
United States Geological Survey Monitoring Results					
Chloroform	10/9/03	RWMC Production	1	0.1	100
	11/13/03	RWMC Production	1.2	0.1	100
	12/18/03	RWMC Production	1.3	0.1	100
	1/15/04	RWMC Production	1	0.1	100
	1/15/04	RWMC Production	1	0.1	100
	2/12/04	RWMC Production	1.2	0.1	100
	3/11/04	RWMC Production	1.1	0.1	100
	4/8/04	RWMC Production	1.3	0.1	100
	5/12/04	RWMC Production	1.4 ^b	0.1	100
	6/10/04	RWMC Production	1.1	0.1	100
	7/8/04	RWMC Production	1.2	0.1	100
	8/12/04	RWMC Production	1.3	0.1	100
	10/9/03	USGS-087	0.1	0.1	100
	4/8/04	USGS-087	0.2	0.1	100
	10/9/03	USGS-120	0.5	0.1	100
Trichloroethene	10/9/03	RWMC Production	2.3	0.1	5
	11/13/03	RWMC Production	2.6	0.1	5
	12/18/03	RWMC Production	3 ^b	0.1	5
	1/15/04	RWMC Production	2.5	0.1	5
	1/15/04	RWMC Production	2.5	0.1	5
	2/12/04	RWMC Production	2.8	0.1	5
	3/11/04	RWMC Production	2.3	0.1	5
	4/8/04	RWMC Production	2.7	0.1	5

Table 4-6. (continued).

Organic Compound	Sample Date	Well	Sample Concentration (µg/L)	Quantitation Limit or Minimum Reporting Level (µg/L)	MCL (µg/L)
Trichloroethene	5/12/04	RWMC Production	3^b	0.1	5
	6/10/04	RWMC Production	2.4	0.1	5
	7/8/04	RWMC Production	2.5	0.1	5
	8/12/04	RWMC Production	3^b	0.1	5
	10/9/03	USGS-087	0.7	0.1	5
	4/8/04	USGS-087	0.7	0.1	5
	10/9/03	USGS-120	0.9	0.1	5
1,1,1-TCA	10/9/03	RWMC Production	0.5^b	0.1	200
	11/13/03	RWMC Production	0.5^b	0.1	200
	12/18/03	RWMC Production	0.5^b	0.1	200
	1/15/04	RWMC Production	0.5^b	0.1	200
	1/15/04	RWMC Production	0.5^b	0.1	200
	2/12/04	RWMC Production	0.5^b	0.1	200
	3/11/04	RWMC Production	0.5^b	0.1	200
	4/8/04	RWMC Production	0.5^b	0.1	200
	5/12/04	RWMC Production	0.5^b	0.1	200
	6/10/04	RWMC Production	0.5^b	0.1	200
	7/8/04	RWMC Production	0.5^b	0.1	200
	8/12/04	RWMC Production	0.5^b	0.1	200
	10/9/03	USGS-087	0.2	0.1	200
	4/8/04	USGS-087	0.2	0.1	200
	10/9/03	USGS-120	0.3	0.1	200

a. Concentrations with a "J" subscript were positively identified in the sample and assigned a "J" data qualifier flag. The qualifier flag was assigned, because the recovery of one of the surrogates was slightly above the upper control limit. The reported concentrations might not be an accurate representation of the amount actually present in the sample and should only be used as estimated quantities. As a result, J-flag data were not considered for the maximum concentration level.

b. **Bold font** indicates maximum concentration detected.

1,1,1-TCA = 1,1,1-trichloroethane

MCL = maximum contaminant level

RWMC = Radioactive Waste Management Complex

USGS = U.S. Geological Survey

Chloroform was detected in Well A11A31 above a quantitation limit of 1 µg/L, and in Wells USGS-87, USGS-120, and the RWMC Production Well above a minimum reporting level of 0.1 µg/L. The maximum concentration of chloroform in FY 2004 was 1.4 µg/L, down from 1.7 in FY 2003. Trichloroethene was detected in Wells A11A31, M7S, and M16S above a quantitation limit of 1 µg/L, and in Wells USGS-87, USGS-120, and the RWMC Production Well above a minimum reporting level of 0.1 µg/L. The maximum concentration in FY 2004 was 3, the same as in FY 2003.

1,1,1-Trichloroethane was not detected in any WAG 7 monitoring wells above a quantitation limit of 1 µg/L. However, 1,1,1-trichloroethane was detected in the RWMC Production Well and Wells USGS-87 and USGS-120 above a minimum reporting level of 0.1 µg/L. The maximum 1,1,1-trichloroethane concentration in FY 2004 was 0.5 µg/L, down slightly from 0.6 in FY 2003. Toluene was detected consistently in Wells M7S, M15S, and A11A31, and the maximum concentration in FY 2004 was 24 µg/L, down from 47 in FY 2003. Samples were analyzed for up to 54 other organic compounds, but

none were detected above the quantitation limits (WAG 7 wells) or minimum reporting levels (USGS wells).

4.4.4 Summary

Other organics detected during sampling at the RWMC include chloroform, 1,1,1-TCA, TCE, Freon-113, 1,1-dichloroethane, chloromethane, and toluene. All organics, except for toluene, were detected in waste zone soil gas.

During aquifer monitoring in FY 2004, only four other organic compounds (i.e., TCE, 1,1,1-TCA, chloroform, and toluene) were detected in 68 samples. All sample results were below MCLs. Toluene had the highest concentration (i.e., 24 µg/L) measured in Well M15S. The maximum TCE concentration (i.e., 3 µg/L), the maximum chloroform concentration (i.e., 1.4 µg/L), and the maximum 1,1,1-TCA concentration (i.e., 0.5 µg/L) were all from the RWMC Production Well.

Detections of TCE and 1,1,1-TCA are not surprising, because those were components of Series 743 sludge. Chloroform detections also are not surprising, because it is likely being produced by degradation of the CCl₄. Detections of the other organics like Freon-113 and 1,1-dichloroethane (soil gas), and toluene (groundwater) are low-level detections and will continue to be monitored.

5. INORGANIC CONTAMINANTS

Numerous anion and cation analysis results were significantly above soil-moisture (lysimeter) background concentrations in FY 2004, and a few results exceeded MCLs. Most anions and cations are not COCs and have little to no associated risk; however, some are very mobile (e.g., chloride and sodium) and provide good early warning indicators of contamination movement in the vadose zone at the SDA. The analysis results of many cations varied drastically in FY 2004. Many of the extreme values seem implausible, because of their inconsistency with past sampling results. In all probability, many of these extreme values are not representative of conditions in the vadose zone. Many of the maximum range values listed in the tables below were not replicated in subsequent sampling events. In addition, some of the high values are possibly analytical anomalies, even though the reported data passed evaluation scrutiny. Interpretation of such inconsistent results is difficult, because many of the anions and cations are indigenous to the environment and are naturally variable. Interpretation of analytical data in the vadose zone is also compounded by the presence of magnesium chloride brine dust suppressant, leachates from waste, possible corrosion of the lysimeter units, and potential analytical anomalies. Many of the cations data are not providing useful information at this point. Only those cations data providing useful information are discussed below.

Each quarter, approximately 400 inorganic analysis results are generated; therefore, to reduce the size of the tables, analytes that exceeded background concentrations and MCLs during FY 2004 are shown with the concentration range observed during FY 2004, except for nitrates. Because nitrates are one of the COCs for OU 7-13/14, they are discussed separately in Section 5.1, followed by a discussion of other inorganic contaminants in Section 5.2.

5.1 Nitrates

5.1.1 Waste Zone

Eighteen waste zone lysimeters were sampled every quarter in FY 2004, and Lysimeters 741-08-L1 and 743-18-L2, located in Pits 10 and 4, respectively, were the only waste zone lysimeters to yield soil moisture samples. The sample volume was very small and allocated to radionuclide analyses. Therefore, nitrate (as nitrogen) analyses were not performed on waste zone soil moisture samples in FY 2004.

5.1.2 Vadose Zone

5.1.2.1 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for nitrates, which were detected in all three samples (see Table 5-1).

5.1.2.2 Lysimeter Samples at Depths of 0–35 ft. Twelve nitrate (as nitrogen) analyses were performed on samples collected from nine lysimeter wells in and around the SDA in FY 2004, with three detections above local soil-moisture background and above the MCL (see Table 5-2). The primary drinking water MCL is not applicable to soil-moisture samples, but it is used as a basis for comparison.

Nitrate concentrations in the shallow region of the vadose zone during FY 2004 show wide variations, ranging from 0.4 mg/L in Well PA01 to 99.8 mg/L in Well PA02. Background levels of nitrate in the vadose zone outside the SDA typically range from 0.1–11.4 mg/L. The highest nitrate concentrations were measured in Well PA02, which is adjacent to Pad A where nitrate-laden waste is buried. Nitrate concentrations at well location PA01 showed a sudden and significant increase in FY 2004

(see Figure 5-1), where concentrations at Well W25 showed a gradual but steady increase over time (see Figure 5-1). Nitrates in the Pad A area appear to have migrated to a depth of about 30 m (100 ft); nitrate concentrations at this 30-m (100-ft) depth also are above background (see results of Lysimeter I4S:DL11 in Table 5-3). Another area where elevated nitrate levels are consistently measured is west of Pit 4 in two adjacent wells (i.e., Wells 98-4 and W-25). A few hundred feet west of this location, at a 28-m (92-ft) depth, is Well I2S, which also contains elevated and trending nitrate concentrations (see results of Lysimeter I2S:DL11 in Table 5-3 and Figure 5-2).

Table 5-1. Nitrate detected in soil samples collected from lysimeter installation core hole drilled in the east end of the Subsurface Disposal Area.

Analyte	Sample Date	Sample Location	Sample Result (mg/kg)	Method Detection Limit (mg/kg)	INL Soil Background UTL ^a (mg/kg)	Soil Hazard Index = 1 ^b (mg/kg)
Nitrate-N	04/26/04	RWMC-2005	6.01	0.56	NE	NA
			8.88	0.56	NE	NA
			5.33	0.56	NE	NA

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Concentration at which noncarcinogenic health effects can occur.

INL = Idaho National Laboratory

NA = not applicable

NE = not established

UTL = upper 95% tolerance limit with 95% confidence

Table 5-2. Nitrate (as nitrogen) concentration above local soil-moisture background in the 0–35-ft depth interval of the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background ^a (mg/L)	MCL ^b (mg/L)
Nitrate-N	10/28/03	PA02:L16	8.7	99.8^c	11.4	10
	10/28/03	W25:L28	15.5	33.9^c	11.4	10
	01/26/04	PA02:L16	8.7	88.9_J^c	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flag was assigned to the January result because the laboratory was unable to perform an analytical quality check to assess matrix interference. The result is usable, but should only be used as an estimated quantity.

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

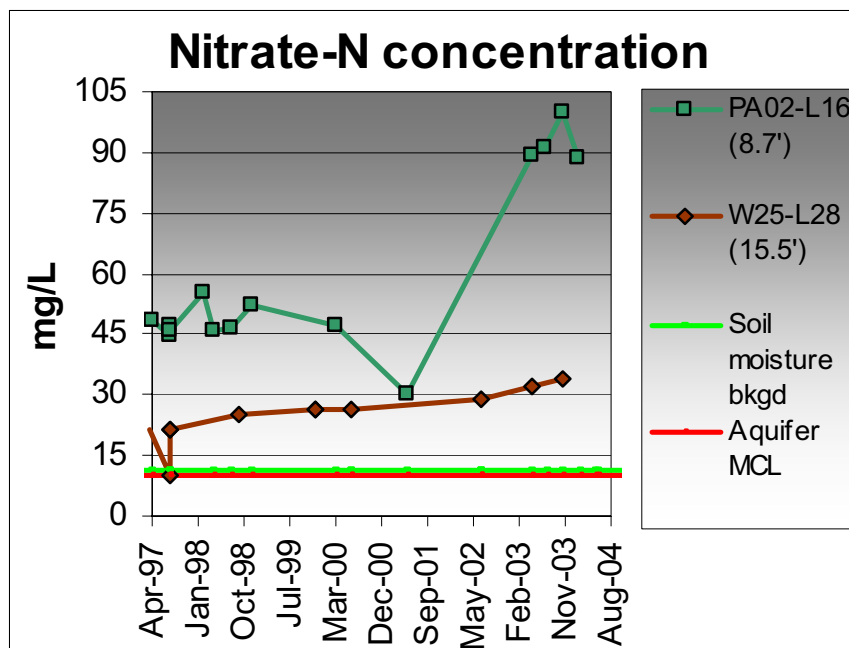


Figure 5-1. Lysimeters in the Subsurface Disposal Area vadose zone exhibiting concentration trends from 1997 through August 2004.

Table 5-3. Nitrate (as nitrogen) concentrations above local soil-moisture background in the 35–140-ft depth interval of the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background ^a (mg/L)	MCL ^b (mg/L)
Nitrate-N	10/28/03	D06:DL02	44	14.8^c	11.4	10
	10/27/03	I-2S:DL11	92	106^c	11.4	10
	10/28/03	I-4S:DL15	97	15.7^c	11.4	10
	10/27/04	TW1:DL04	101.7	16.0^c	11.4	10
	02/02/04	I-2S:DL11	92	98.6^c	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b).

EPA = U.S. Environmental Protection Agency

MCL = maximum contaminant level

SDA = Subsurface Disposal Area

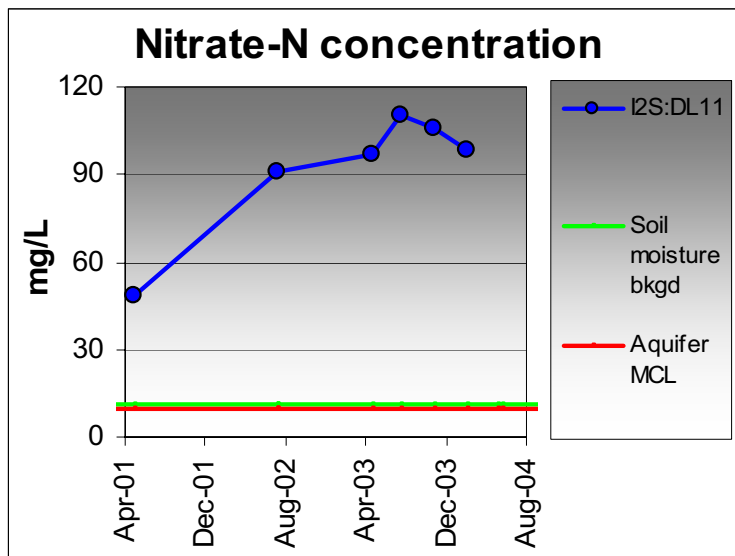


Figure 5-2. Lysimeter in the Subsurface Disposal Area vadose zone exhibiting concentration trend.

5.1.2.3 Lysimeter Samples at Depths of 35–140 ft. Twenty-one nitrate (as nitrogen) analyses were performed on samples collected from 13 lysimeter wells in and around the SDA in FY 2004, with five detections above local soil-moisture background (see Table 5-3). All five detections exceeded the drinking water MCL. The primary drinking water MCL is not applicable to soil-moisture samples, but is used as a basis for comparison. Nitrate concentrations in the intermediate vadose zone also show wide variations, ranging from 0.1 mg/L in Well O2S to 110 mg/L in Well I2S. Wells monitored in this depth interval around Pad A (i.e., D06, TW1, and I4S) generally have slightly elevated nitrate concentrations in the range of 12–16 mg/L. Nitrate concentrations in Well I4S show nitrate contamination has migrated to about the 100-ft depth around Pad A. This lysimeter well is located in the same vicinity as the high and trending nitrate concentrations observed in PA02. Well I2S has the highest nitrate concentration observed in the 35–140-ft depth interval, and the concentration is increasing at a fairly significant rate (see Figure 5-2).

5.1.2.4 Lysimeter Samples at Depths of 140 to 250 ft. Twenty-eight nitrate (as nitrogen) analyses were performed on samples collected from 16 lysimeters and three perched water wells in and around the SDA in FY 2004, with one lysimeter result above local soil-moisture background and the MCL, and three perched water results above aquifer background (see Table 5-4). The primary drinking water MCL is not applicable to soil-moisture samples, but is used as a basis for comparison. Nitrate concentrations detected in the deep vadose zone soil moisture and perched water are near background levels and indicate much less variation than do nitrate concentrations in the shallow and intermediate vadose zone. Nitrate concentrations in this depth interval range from 0.13 to 15.7 mg/L. It should be noted that the concentration of 15.7 mg/L is associated with Well TW1:DL03. This the first time a soil-moisture sample has been collected from Well TW1:DL03, so it is interesting to observe nitrate concentrations typical of what is usually detected in TW1:DL04 at 32 m (102 ft). One sample result, however, is not sufficient evidence to surmise that nitrates have migrated to 69 m (227 ft), especially because a remote possibility exists that the DL03 and DL04 sample lines could have been switched during this sampling event or that samples were mislabeled.

Table 5-4. Nitrate (as nitrogen) concentrations above local soil-moisture background at depths greater than 140 ft in the Subsurface Disposal Area vadose zone soil moisture (lysimeter).

Analyte	Sample Date	Well: Lysimeter	Well: Lysimeter Depth (ft)	Sample Result (mg/L)	Local Soil-Moisture Background ^a (mg/L)	MCL ^b (mg/L)
Nitrate-N	01/26/04	TW1:DL03	226.9	15.7 ^c	11.4	10

a. Local soil-moisture background values are the upper concentration ranges obtained from up to 50 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).

b. The MCLs are from the "National Primary Drinking Water Standards" (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.

c. **Red bold font** indicates sample concentrations that exceed the MCL (see Footnote b).

EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
SDA = Subsurface Disposal Area

5.1.3 Aquifer

Fifty nitrate (as nitrogen) analyses were performed on samples collected from 15 RWMC monitoring wells around the RWMC in FY 2004, with no detections above the SRPA background concentration of 1 to 2 mg/L established by Knobel, Orr, and Cecil (1992). At the end of 2004, the frequency at which the RWMC aquifer was monitored changed to biannually; thus, only data from the first three quarters of FY 2004 are available and shown in Figure 3-4. Low levels of nitrates were detected in all RWMC aquifer samples at concentrations characteristic of SRPA background levels, except for Well M6S. Nitrate concentrations in FY 2004 ranged from 0.3 mg/L in Well M13S to 2.0 mg/L in M6S. All results were below the primary drinking water MCL of 10 mg/L. The nitrate concentration measured in January 2004 in Monitoring Well M6S (i.e., 2.02 mg/L) could be construed as exceeding SRPA background (2 mg/L); however, interpretation is dependent on how the result is mathematically rounded. The M6S result at 2.02 mg/L is considered to be representative of aquifer background, but will continue to be monitored for concentration increases. Nitrate levels in M6S have exhibited increasing concentration trends since 1992; however, that trend appears to have stabilized in 2002 at concentrations near the SRPA background (see Figure 5-3).

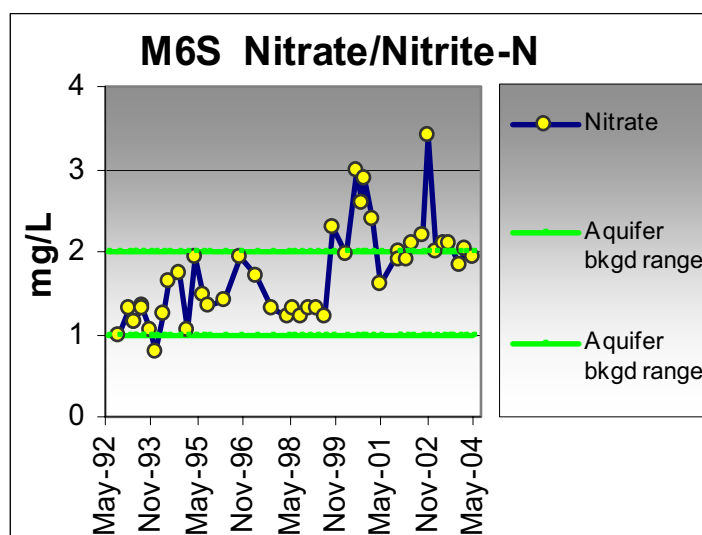


Figure 5-3. Concentration of nitrates (as nitrogen) in Radioactive Waste Management Complex Aquifer Monitoring Well M6S from 1992 to May 2004.

5.1.4 Summary of Nitrates

Low levels of nitrates were detected in all aquifer-monitoring wells in the vicinity of the RWMC in FY 2004 at concentrations characteristic of background levels typically found in the SRPA.

Of the 61 vadose zone soil-moisture and perched water samples collected and analyzed for nitrates in FY 2004, 11 results were above background levels and nine of those 11 exceeded the primary drinking water MCL. Significant concentration trends were associated with Lysimeters PA02:L16 and I2S:DL11, providing evidence that nitrates have migrated to about 30 m (100 ft) in the vadose zone. Nitrate concentrations are highest in the 0–11-m (0–35-ft) and 11–43-m (35–140-ft) regions of the vadose zone, and are most prevalent in lysimeter wells located around the Pit 5 and Pad A area (i.e., Wells D06, I4S, PA02, and TW1), the west end of the SDA (i.e., Well I2S), the west end of Pit 4 (i.e., Wells 98-4 and W25), and the Acid Pit (Well W08). Significant concentration trends are evident at lysimeter well locations PA01 and I2S.

5.2 Other Inorganic Contaminants

Numerous anions and cations analysis results were above background in samples collected from RWMC aquifer-monitoring wells and vadose zone soil moisture in FY 2004. Many of these anions and cations have high concentrations that exceed aquifer MCLs. Anion and cation contaminants detected in the vadose zone have relatively high concentrations, and many are attributed to dust-suppression activities at the SDA up to 20 years ago. In 1984, 1985, 1992, and 1993, magnesium chloride brine was applied to roads in the SDA to suppress dust. The chemical constituents of the brine are now widely distributed in the vadose zone at the SDA, and most of the elevated concentrations of cations and anions can be related to the brine application. The primary anion in the brine is chloride, but bromide and sulfate also are present at high concentrations. Elevated calcium, sodium, potassium, and magnesium are related to the brine application. Brine affects the chemistry of soil water by ion exchange, as evidenced by elevated brine constituents and changes in anion ratios. Higher mineral content and altered chemistry of the soil water accelerates the migration of some waste contaminants. Because the chemical constituents of brine are corrosive, they likely have contributed to the premature corrosion and deterioration of waste containers in the SDA.

Brine constituents are consistently detected during routine monitoring of vadose zone soil moisture to depths around 30 m (100 ft), with detections at depths around 67 m (220 ft). Vadose zone sampling and analysis data evaluated in the *Fate of Magnesium Chloride Brine Applied to Suppress Dust from Unpaved Roads at the INEEL Subsurface Disposal Area* (Hull and Bishop 2003) report show evidence that brine has definitely migrated at least 73 m (240 ft) deep at the SDA since 1984, and can move laterally. Vertical migration rates of 6–40 m (20–130 ft) per year were determined for brine constituents (Hull and Bishop 2003), and, at this rate, brine constituents could have reached the aquifer by now. Even though routinely detected, chemical constituents of brine generally are not reported unless concentrations begin to increase or change suddenly, or constituents are detected at deeper depths. Lysimeter and aquifer results for other inorganic contaminants are addressed in the following sections.

5.2.1 Vadose Zone

5.2.1.1 Anions and Metals in Soil Moisture and Perched Water. Numerous anions and cations were detected above soil moisture and perched water background concentrations in FY 2004. Some results also exceeded MCLs. The MCLs are not applicable to vadose zone soil-moisture sample results, but are applied by OU 7-13/14 as a means of comparison. Because of the large number of reportable inorganic analysis results, a table listing each result for each lysimeter for each quarter is not included.^h However, Table 5-5 reports the analytes detected above background and associated concentration ranges observed in FY 2004.

h. Reportable inorganic analysis results are reported in OU 7-13/14 quarterly reports to the U.S. Department of Energy Idaho Operations Office.

Table 5-5. Positive detections of anions and cations above background in Subsurface Disposal Area vadose zone soil-moisture (lysimeter) samples in FY 2004.

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (mg/L)	Local Soil-Moisture Background ^a (mg/L)	MCL ^b (mg/L)	Wells with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Aluminum	1, 2, 3, 4	0.142–3.31^c	0.140	—	O-4	USGS-92(PW)
Antimony	3	0.031–1.06^{d,e}	0.031	0.006 ^c	O-2	None
Arsenic	3, 4	0.045–0.79^{d,e}	0.040	0.010 ^c	O-2	W23, O-7
Barium	1, 2, 3, 4	0.167–0.87^c	0.150	2.00	DE7	DE7
Bromide	1, 2, 3	2.16–12.5^c	2.00	—	I-1S	PA02, TW1, D06,
Cadmium	1, 3	0.005–0.17^d	0.003	0.005	O-4	None
Calcium	1, 2, 3, 4	181–1,640^c	180	—	I-1S	D06, I-1S, USGS-92
Chloride	1, 2, 3	362–4,610^c	340	—	I-1S	USGS-92(PW), PA02, D06, TW1
Chromium	1, 2, 3, 4	0.014–43.2^d	0.013	0.100	O-4	W23, 98-5, O-7
Cobalt	1, 3, 4	0.008–1.09^c	0.004	—	O-4	None
Copper	3	0.242–0.882^c	0.190	1.30	O-2	None
Fluoride	3	2.45–5.74^d	2.00	4.00	PA01	PA01
Iron	1, 2, 3, 4	0.262–471^c	0.210	—	IE7	DE7, USGS-92(PW), IE6
Lead	1, 3	0.026–0.047^{d,e}	0.016	0.015 ^c	IE6	None
Magnesium	1, 2, 3, 4	69.8–655^c	64.1	—	I-1S	D06, PA02, I-1S, USGS-92(PW)
Manganese	1, 2, 3, 4	1.17–17.3^c	0.99	—	O-4	DE7
Nickel	1, 3, 4	0.223–68.2^{d,e}	0.17	0.10 ^c	O-2	O-7, D06
Nitrate-N	1, 2	14.8–106^c	11.4	10 ^c	I-2S	PA02, D06, W25, I-2S
Potassium	1, 2, 3, 4	16.1–2,650^c	16	—	D-10(PW)	D06, I-1S, USGS-92 (PW)
Selenium	1, 3, 4	0.020–0.17^d	0.020	0.05	I-1S	D06, PA01
Silver	3, 4	11.3–53.7^c	0.006	—	O-2	O-2

Table 5-5. (continued).

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (mg/L)	Local Soil-Moisture Background ^a (mg/L)	MCL ^b (mg/L)	Wells with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Sodium	1, 2, 3, 4	438–3,200^c	390	—	D06	PA02, D06, W23, PA01, USGS-92(PW)
Sulfate	1, 2, 3	603–4,210^c	596	—	D06	D06, USGS-92(PW)
Vanadium	3, 4	0.0274–0.101^c	0.027	—	O-4	PA01
<p>a. Local soil-moisture background values are the upper concentration ranges obtained from up to 57 soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, and the O-series wells).</p> <p>b. The MCLs are from the “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA. The MCLs for vadose zone water samples are applicable to perched water, but not to soil-moisture (lysimeter) samples. The MCLs for lysimeter sample results are provided here only as a basis for comparison.</p> <p>c. Black bold font indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations (see Footnote a). Concentration values with a “J” subscript denote that “J” data validation qualifier flags were assigned. The “J” flags were assigned to the nitrate results because the 2-day holding time requirement was exceeded by 1 day. The “J” flags were assigned to the copper results because the serial dilution sample was outside the $\pm 10\%$ difference requirement. The results are usable, but should only be used as estimated quantities.</p> <p>d. Red bold font indicates sample concentrations that exceed the MCL (see Footnote b).</p> <p>e. The MCL was applied, even though its upper limit is lower than the soil-moisture background.</p> <p>EPA = U.S. Environmental Protection Agency MCL = maximum contaminant level SDA = Subsurface Disposal Area</p>						

Some of the high metal concentrations observed in FY 2004 appear to be uncharacteristic and abrupt increases; however, in many cases subsequent sample results show concentrations have returned to normal, except in cases where follow-up samples have not been collected yet. Currently, no anions or cations exhibit noticeable concentration trends.

Cation concentrations exceeding MCLs in the vadose zone in FY 2004 were antimony, arsenic, cadmium, chromium, lead, nickel, and selenium. Historically, no consistent detections of antimony, cadmium, or lead were found in the SDA vadose zone; however, arsenic, chromium, nickel, and selenium are often detected above MCLs, but only in specific monitoring wells (see Table 5-5). Arsenic, chromium, and nickel are primarily detected above MCLs in Well O-7 located about 0.8 km (0.25 mi) south of the SDA; however, arsenic is also above the MCL in the SDA at lysimeter location W23:L07. Selenium appears to be associated with only Well D06 near Pad A.

Nickel and chromium are not abundant rock-forming elements, and other natural elements (e.g., aluminum) are low in this sample; therefore, the metals in Lysimeter O7-DL28 do not appear to be suspended solids from natural rock materials. The geochemical behavior of iron, chromium, and nickel are very different. Iron has a higher solubility at low redox potential, chromium is higher in solubility at high redox potential, and nickel is not affected by redox potential. Therefore, the metals do not appear to be related to geochemical conditions in the vadose zone. The ratio of iron to chromium to nickel in this water sample is typical of the ratio of the same metals in stainless steel. Conjecture is that elevated metals in the sample from Lysimeter O7-DL28 are likely the result of stainless steel from lysimeter materials suspended in the sample that were dissolved during sample digestion.

Selenium is often detected above local soil-moisture background concentrations in various lysimeter samples; however, only two lysimeter wells near Pad A (D06 and PA01) exhibit consistent detections with concentrations that are either near or exceed the MCL. Selenium is a small component of the earth's crust and rocks; however, the source of selenium near Pad A has yet to be identified. Selenium is consistently detected in some RWMC aquifer-monitoring wells (see discussion in Section 5.3).

Concentrations of barium, iron, and manganese in deep lysimeter Well DE7 are significantly above local soil-moisture background, and increasing. No regulatory limits are associated with these analytes; therefore, no actions are required. These analytes are mentioned only because previous samples collected from this lysimeter well were discolored and had an unidentifiable organic odor, and a relationship may exist between elevated cation concentrations and unidentified VOCs. Methods to identify the VOCs are ongoing.

5.2.1.2 Magnesium Chloride Brine. In FY 2004, lysimeter wells with evidence of brine contamination were consistent with wells where brine was previously identified (Hull and Bishop 2003) (i.e., Wells 8802D, 98-1, D06, I-1S, I-4S, I-4D, O-4, PA02, and TW1). Brine contamination also was detected in Well D15 outside the SDA, and in Wells DE7 and IE7, which were installed in 2003. Wells 98-1 and PA02 have the highest measured chloride concentrations, along with other brine constituents, in the shallow vadose zone with up to 11,000 mg/L. Well 98-1 is located in the southeast corner of the SDA, and Well PA02 is located adjacent to Pad A. In the intermediate vadose zone, chloride levels have reached 5,300 mg/L in Well I-1S. Two perched water wells and two lysimeter wells in the deep region of the vadose zone (i.e., Wells 8802D, USGS-92, DE7, and I-4D) show chloride levels about 90–800 mg/L, which are above the perched water background concentration of 21 mg/L and soil-moisture background of 340 mg/L. Evidence from Lysimeters DE7:DL36 and DE7:DL37 indicate brine has migrated to 115 and 126 m (377 and 413 ft) at the SDA. The chloride concentration at three of these deep locations is greater than 350 mg/L, and the chloride:bromide concentration ratios are around 400:1, indicating the contamination at these depths is indeed magnesium chloride brine (see Table 5-6). Some evidence also suggests the brine may be responsible for some of the elevated anion and cation

Table 5-6. Magnesium chloride brine constituents detected in the deep vadose zone from approximately 200–400 ft in FY 2004.

Brine Well	Date	Chloride (mg/L)	Magnesium (ug/L) ^a	Sulfate (mg/L) ^{a,b}	Sodium (ug/L) ^a	Potassium (ug/L) ^a	Bromide (mg/L) ^{a,b,c}	Calcium (ug/L) ^a	Br:Cl Ratio
8802D (220 ft)	05/01/03	770	—	500	—	—	1.80	—	428
	05/06/04	597	80,100	453	401,000	8,540	1.68	95,200	355
USGS-92 (214 ft)	10/29/03	81.7	21,900	64.4	104,000	13,900	0.1 _U	57,100	—
	02/02/04	88.6	21,100	71.6	97,600	9,440	1.2 _{UJ}	49,400	—
	05/06/04	92.7	21,100	68.2	120,000	9,280	0.0 _U	52,100	—
DE7:DL36 (377 ft)	10/27/03	368	10,400	24	815,000	22,100	4.4	61,700	84
	05/05/04	587	39,100	0.9	159,000	16,100	1.74	190,000	337
	08/30/04	—	51,600	—	139,000	15,700	—	214,000	—
	11/16/04	780	60,000	0.0 _U	116,000	15,200	2.2	217,000	355
DE7:DL37 (413 ft)	10/27/03	671	84,100	19	143,000	24,800	1.0 _U	152,000	671
	01/26/04	660	90,000	12	140,000	15,900	2.2	173,000	300
	05/05/04	757	107,000	3.1	157,000	13,900	2.2	181,000	344
	08/31/04	—	113,000	—	157,000	13,400	—	194,000	—
	11/16/04	671	96,700	20	123,000	11,900	2.2	163,000	358
RWMC soil-moisture background ranges:		22–340	11–64.1K	14–596	44–390K	3.8–16K	0.0–2.0	49–180K	—
RWMC aquifer/perched water background ranges:		9–21	13–19K	17–31	8–18K	1–6K	0.00–0.15	19–46K	—

a. **Bold black font** indicates sample concentrations less than the MCL, but exceeding local soil-moisture background concentrations. Local soil-moisture background values are the upper concentration ranges obtained from soil-moisture samples collected between April 1987 and August 2004 from lysimeter wells located outside of the SDA (i.e., Wells C01, C02, D15, R1935, R1936, and the O-series wells).

b. Subscript “U” means the material was analyzed for and was detected at or above the applicable detection limit. However, the associated value was less than five times the highest positive amount in any laboratory blank.

c. Subscript “J” means the material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise. A “UJ” validation flag is not differentiated from the combined action of a “U” and “J” validation flag.

concentrations in the SRPA beneath the RWMC (see Figure 5-4). Though brine constituents are not COCs, the fact that they are so prevalent in the SDA vadose zone—found as deep as 126 m (413 ft) and possibly the aquifer—means that mobile contaminants from buried waste in the SDA (e.g., C-14, Tc-99, I-129, and uranium) may not be far behind.

5.2.1.3 Subsurface Soil Samples Collected While Drilling Lysimeter Well RWMC-2005.

In April 2004, while drilling lysimeter Well RWMC-2005 in the east end of the SDA (see Figure 2-3), radioactivity above background was detected in the drilling soil returns. Drilling was stopped, and three separate soil samples were collected from these returns. The samples were analyzed for radionuclides, anions, and cations. Six anions and cations were detected with concentrations above background tolerance limits (see Table 5-7). Surficial soil background UTLs are not necessarily applicable to subsurface soils, but are provided here only as a basis for comparison.

5.2.2 Aquifer

Several anions and cations have been detected in concentrations greater than aquifer background values in FY 2004, and one exceeded drinking water MCLs. Lead-analysis results of one sample collected from Well A11A31 in January 2004 exceeded the MCL. Historically, lead has been detected sporadically in this well, and is likely associated with corrosion of the well casing, which is constructed of galvanized steel. Corrosion of the galvanized steel casing also explains why concentrations of aluminum, iron, and zinc also are elevated in this well, because they are all components of galvanized steel.

Elevated concentrations of aluminum, chromium, iron, and sodium were the most widespread and frequently detected metals in FY 2004. Frequently detected anions were chloride and sulfate. Other metals and anions were detected above aquifer background concentrations, but are not widespread and appear unique to some monitoring wells (e.g., arsenic and fluoride are primarily detected in Well M4D, and lead and zinc are mostly associated with Well A11A31). Many of these elevated concentrations may be sampling artifacts, natural elevated concentrations, or constituents of the magnesium chloride dust suppressant. Because of the large number of reportable inorganic analysis results, a table listing each result for each aquifer well for each quarter are not included (see Footnote a). However, Table 8 shows the analytes detected above background and their associated concentration ranges observed in FY 2004.

Many analytes reported in Table 5-8 have historical concentrations above aquifer background levels, but concentrations of these analytes consistently remain below drinking water MCLs and show no observable concentration trends. Only the RWMC monitoring wells exhibiting concentration trends, sudden increases, or other atypical information in FY 2004 are discussed below.

Both filtered and unfiltered samples were collected in FY 2004, and analysis results show some cations exist primarily as suspended solids (i.e., aluminum, iron, lead, and zinc), and other cations are dissolved (i.e., arsenic, chromium, magnesium, nickel, and vanadium). Suspended solids found in the unfiltered samples are most likely from natural sediments in the aquifer or corrosion of well-construction materials; whereas, the dissolved fraction in filtered samples could be contaminants leached from buried waste, chemical constituents of magnesium chloride brine, or minerals dissolved from basalt. However, most reported metals (e.g., aluminum, iron, lead, and zinc) are due to suspended solids in the aquifer or from well-construction materials, except for chromium and magnesium. Most RWMC aquifer-monitoring well samples contain chromium in the dissolved phase and iron and aluminum as suspended solids. This is expected, because under the neutral-to-alkaline pH of the SRPA, and the oxidizing environment, chromium is soluble and iron and aluminum are not.

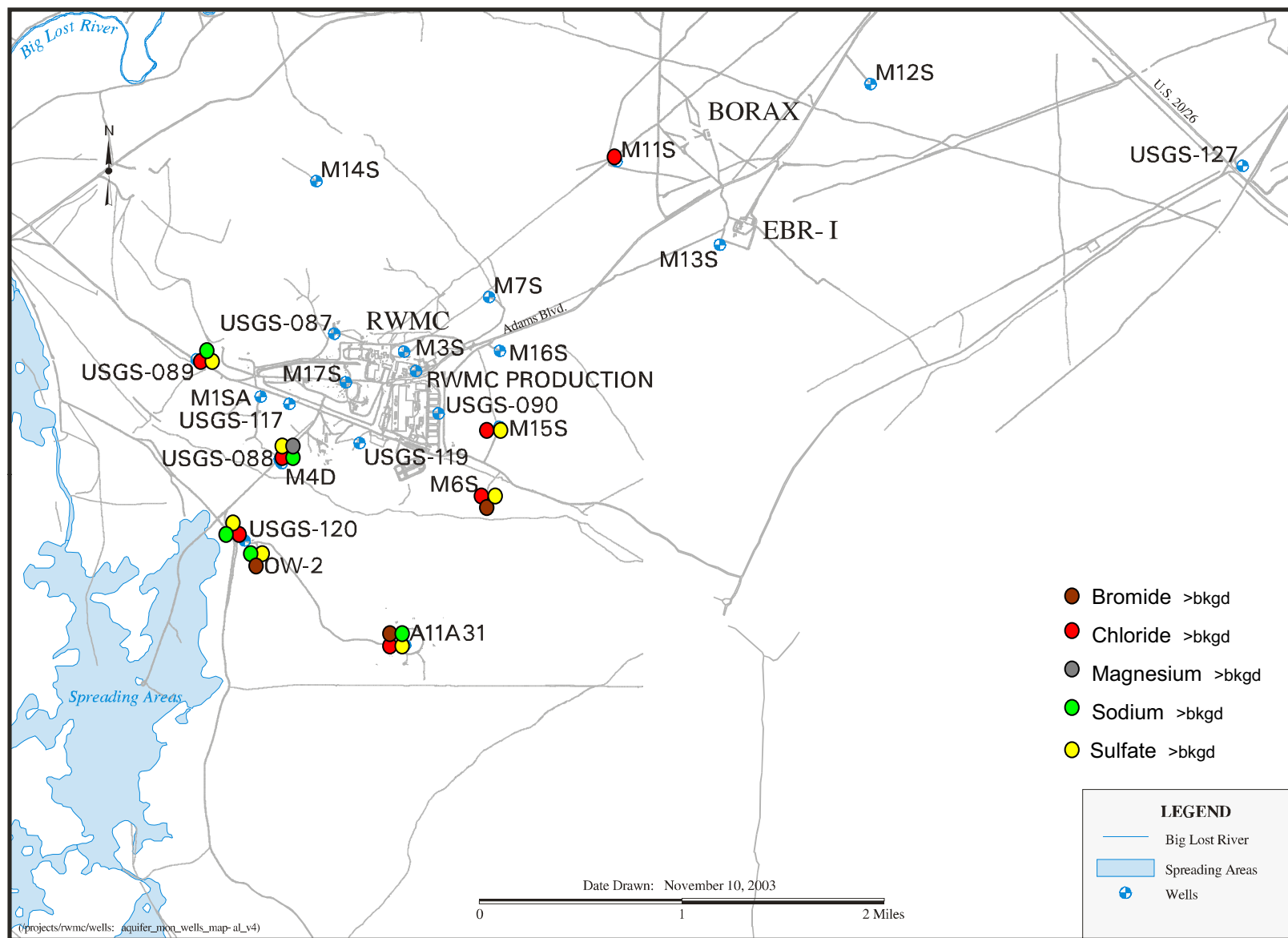


Figure 5-4. Location of the Radioactive Waste Management Complex wells possibly contaminated by magnesium chloride brine or leachates from buried waste.

Table 5-7. Anions and cations detected above upper tolerance limits in soil samples collected from lysimeter installation corehole drilled in the east end of the Subsurface Disposal Area.

Analyte	Sample Date	Sample Location	Sample Result (mg/kg)	MDL (mg/kg)	INL Soil Background UTL ^a (mg/kg)	Soil Hazard Index = 1 ^b (mg/kg)
Arsenic	04/26/04	RWMC-2005	20.2^c	2.39	7.4	23
			21.2^c	2.20	7.4	23
			16.6^c	2.10	7.4	23
Calcium	04/26/04	RWMC-2005	49,400^c	10.9	39,000	NA
			49,100^c	10.0	39,000	NA
			48,600^c	9.58	39,000	NA
Chloride	04/26/04	RWMC-2005	738^c	25	NE	NA
			848^c	24.8	NE	NA
			733^c	24.9	NE	NA
Nitrate-N	04/26/04	RWMC-2005	8.88^c	0.56	NE	NA
Sodium	04/26/04	RWMC-2005	1,470^c	5.54	520	NA
			1,380^c	5.09	520	NA
			1,380^c	4.87	520	NA
Thallium	04/26/04	RWMC-2005	26.8_J^d	9.67	0.68	5.2
			27.7_J^d	8.89	0.68	5.2
			14.6_J^d	8.50	0.68	5.2

a. INL surficial soil background 95% upper tolerance concentration limits for grab samples are not directly applicable to subsurface soils, but are provided here only as a basis for comparison. The surficial soil background tolerance limits were established in 1996 (Rood, Harris, and White 1996).

b. Concentration at which noncarcinogenic health effects can occur.

c. **Black bold font** indicates sample concentrations less than the RBC, but exceeding surficial soil background upper tolerance limits (see Footnote a). Concentration values with a "J" subscript denote that "J" data validation qualifier flags were assigned. The "J" flags were assigned to the thallium results because the percent recovery of the laboratory control sample exceeded the upper control limit. The results are usable, but should be used only as estimated quantities.

d. **Red bold font** indicates sample concentrations greater than a hazard index of 1.

INL = Idaho National Laboratory

MDL = method detection limit

NA = not applicable

NE = not established

RBC = risk-based concentration

UTL = upper 95% tolerance limit with 95% confidence

Table 5-8. Anion and cation concentrations in excess of aquifer background levels or maximum contaminant levels in FY 2004.

Analyte	Sample Quarter (results greater than background)	Sample Concentration Range (µg/L)	Aquifer Background ^a (µg/L)	MCL ^b (µg/L)	Well with Highest Concentration in FY 2004	Wells with Most Detections Above Background Since 1997
Aluminum	1, 2, 3	48.5–337^c	40 ^d	—	A11A31	M17S, M15
Arsenic	2, 3	5.5–11.1^c	5.0	50	M3S	M4D
Bromide	1, 2, 3	170–750^{j, e}	150	—	A11A31	A11A31
Calcium	3	46,600^c	46,000 ^f	—	M3S	M3S
Chloride	1, 2, 3	21,100–38,900^{j, e}	21,000 ^f	—	M15S	M6S, M15S, A11A31
Chromium	1, 2, 3	21.3–89.4^c	22 ^d	100	M15S	M1S, M6S, M15S
Fluoride	1, 2, 3	818–835^c	500	4,000	M4D	M4D
Iron	1, 2, 3	93.2–2,970^c	85 ^d	—	M6S	M6S, M15S, OW2
Lead	2	30^{f, g}	5	15	A11A31	A11A31
Magnesium	1, 2, 3	20,000–22,000^{j, e}	19,000 ^f	—	M6S	M6S
Manganese	2	17.2^c	15 ^d	—	A11A31	M15S, M17S
Nickel	1, 2, 3	11.0–85.2^c	10 ^d	100	M11S	M6S, M11S
Nitrate-N	2	2020^c	2,000	10,000	M6S	M6S
Potassium	1, 2, 3	19,500–23,300^c	6,000 ^d	—	M4D	M4D
Selenium	1, 2, 3	4.1–9.5^{j, e}	4 ^d	50	M6S	M6S
Sodium	1, 2, 3	18,400–48,700^c	18,000 ^f	—	M4D	M4D, OW2, A11A31
Sulfate	1, 2, 3	36,600–74,700^{j, e}	31,000 ^f	—	M6S	M6S, M15S, OW2, A11A31
Vanadium	1, 2, 3	14.1–14.5^c	14.0 ^d	—	M13S	M13S
Zinc	1, 2, 3	265–2,510^c	210 ^d	—	A11A31	A11A31

a. The SRPA background ranges were established in 1992 by the U.S. Geological Survey from samples collected upgradient (i.e., Mud Lake area) and downgradient (i.e., Magic Valley area) of the INL (Knobel, Orr, and Cecil 1992).

b. The MCLs are from “National Primary Drinking Water Standards” (40 CFR 141) established by the EPA.

c. **Black bold font** indicates sample concentrations less than the MCL, but exceeding aquifer background concentrations (see Footnote a). If a background concentration has not been established for a particular analyte, sample results are compared to concentration ranges typically observed in the aquifer at or near the INL (see Footnote e).

Many chromium concentrations in the aquifer beneath the RWMC are significantly above the maximum concentration range found in the SRPA around the INL. Total chromium concentrations in FY 2004 ranged from about 5 pCi/L in Well M4D to 89 pCi/L in Well M15S. Total chromium includes contributions from dissolved and solid chromium as well as chromium in various oxidation states (e.g., Cr^{3+} and Cr^{6+}). Total chromium concentrations in four RWMC monitoring wells (i.e., Wells M1SA, M6S, M11S, and M15S) historically exceed concentrations typically detected in the SRPA around the INL (1–22 $\mu\text{g/L}$), as determined from data published by Knobel et al. (1999), which excludes atypically high concentrations measured around the RTC. Wells M1SA and M6S have shown a gradually increasing concentration trend over the past 11 years, and Wells M11S and M15S began their upward trend in the past couple of years (see Figure 5-5). The USGS monitoring wells south of the SDA (Wells USGS-88, -89, and -119) also have elevated concentrations of chromium. Even though Wells USGS-088, USGS-089, and USGS-119 have not been analyzed recently for chromium (1996 is most recent), it is conjectured that the chromium levels in those wells would still be elevated and roughly comparable to these measured in the WAG 7 aquifer-monitoring wells located on the south and southeast side of the RWMC. Most of the wells with elevated chromium concentrations are located immediately south and southeast of the RWMC (see Figure 5-6), except for Well M11S, which is about 3 km (2 mi) upgradient of the RWMC. This pattern of chromium occurrence is consistent with other elevated analytes (i.e., bromide, chloride, magnesium, sodium, sulfate) in these particular wells; this would be expected if contaminants were leaching from the SDA and accumulating in wells to the south and southeast due to the presence of a low flow or low permeability zone (Wylie and Hubbell 1994).

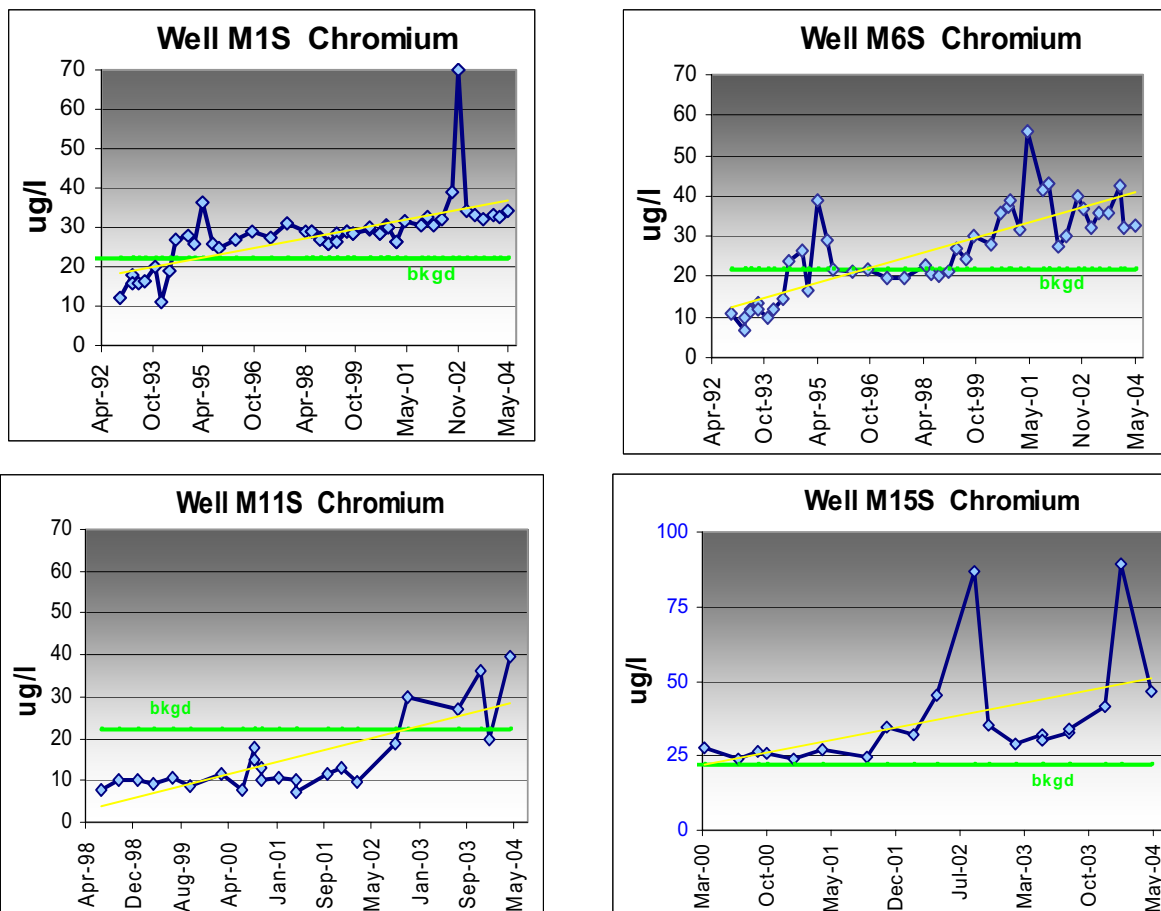


Figure 5-5. Radioactive Waste Management Complex aquifer-monitoring wells with increasing chromium concentrations.

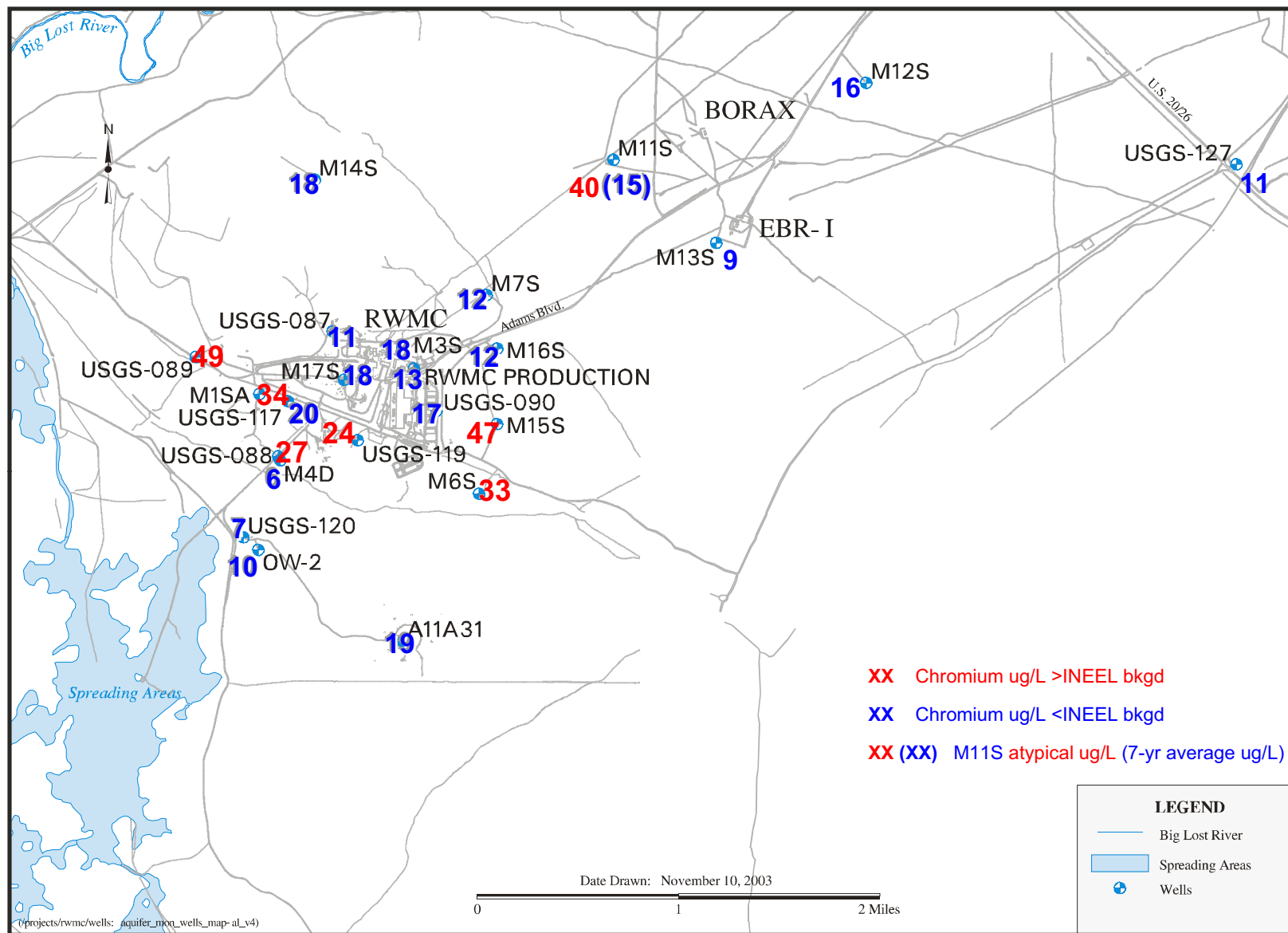


Figure 5-6. Chromium concentrations in wells at the Radioactive Waste Management Complex.

Chromium in Well M11S contains a significant fraction of suspended solids, indicating that the chromium in this well is likely associated with corrosion of the stainless steel well-construction materials. Chromium in Wells M1SA, M6S, and M15S are mostly in the dissolved phase indicating chromium could be from high natural abundance in basaltic formations beneath the RWMC or from SDA waste leachates. Well M15S also has a substantial fraction of chromium that exists as a suspended solid, suggesting corrosion of well-construction materials. Concentrations of dissolved chromium in the SRPA, upgradient and downgradient of the INL, range from 1–50 ug/L (Knobel, Orr, and Cecil 1992); whereas, concentrations on or near the INL range from 1–190 ug/L, with the highest concentrations near the RTC (Knobel et al. 1999). Whether elevated levels of chromium in wells located at the south-southeast side of the RWMC are from the SDA, RTC, or natural occurrences has not been absolutely determined. Chromium concentrations within a 2-km (1-mi) radius of the RWMC are generally higher than concentrations farther away than 2 km (1 mi) (see Figure 5-7). Further sampling, analysis, and data evaluation are necessary to positively determine whether elevated chromium concentrations in the aquifer near the RWMC are from waste leachates, upgradient influences, or natural phenomena.

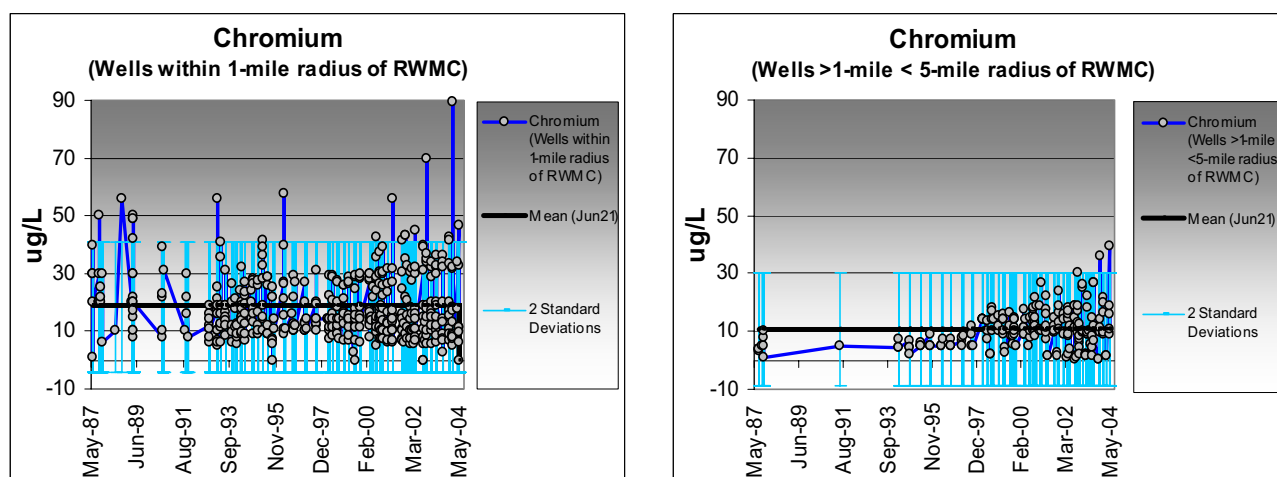


Figure 5-7. Chromium concentrations within a 1-mi radius are generally higher than concentrations within 1–5-mi radius of the Radioactive Waste Management Complex.

In addition to chromium, other metals (magnesium and sodium) and anions (bromide, chloride, and sulfates) are detected at elevated concentrations in the aquifer around the RWMC that are exhibiting a spatial pattern similar to chromium (see Figure 5-4). Many of these metals and anions appear to be characteristic of magnesium chloride brine, but could also be leachates from buried waste, or could possibly be groundwater contaminants from the RTC (e.g., sulfates) or INTEC (e.g., chlorides).

Upgradient influences are unlikely because H-3 (common to both facilities) was not detected in the affected RWMC wells. Evidence suggests that the SDA is the source of elevated bromide, chloride, magnesium, sodium, and sulfate in the SRPA south-southeast of the RWMC. However, brine may not be entirely responsible for these contaminants, because high chlorides, sodium, and sulfates have been measured in nearby Wells USGS-88 and USGS-89 since 1977, long before brine was applied to roads in the SDA. Conversely, other USGS wells in this area with a 17-year sampling history (i.e., Wells USGS-117 and USGS-119) do not show elevated concentrations of these anions or cations. Aquifer-sample chemistry in this area of the RWMC should be somewhat comparable, because screened intervals of each well overlap, and pump depths are within a 20-m (65-ft) depth interval of each other, except for Wells M11S and M15S. Even though most well samples in this area are collected at similar depths, the anion and cation chemistry, including their ratios, are very different. Hydrologic or geologic

components, which are likely in this area, affect the chemistry. Further sampling, analysis, and data evaluation are necessary to positively determine whether observations in the aquifer south–southeast of the RWMC are from brine, waste leachates, or natural phenomena.

Analyte concentrations in Well M4D are unlike all other RWMC aquifer-monitoring wells. Potassium, sodium, and gross beta concentrations are about six times higher than in other wells, and arsenic is approximately two times higher; whereas, calcium and magnesium are approximately five times lower, and naturally occurring uranium concentrations are approximately two times lower than other RWMC wells. Sodium has a slightly increasing concentration trend; whereas, the other analytes show a relatively flat or slightly decreasing trend. Well M4D is much deeper than other RWMC aquifer-monitoring wells (i.e., 117 vs. about 198 m [838 vs. about 650 ft]), and the difference in chemistry between this well and the other RWMC wells suggests that groundwater at deep levels is isolated from the shallower groundwater.

5.2.3 Summary of Other Inorganic Contaminants

The source of some anions and cations detected above background in RWMC aquifer and vadose zone soil, and soil-moisture samples cannot be absolutely determined at this time. Many of these anions and cations are of concern because they could be contaminants from buried waste or chemical components of magnesium chloride brine. The constituents of brine do not pose a serious risk to human health or the environment. Brine constituents may be useful as chemical tracers indicative of contaminant migration in the vadose zone beneath the SDA; however, they may promote corrosion of waste containers.

Chromium concentrations in most RWMC aquifer-monitoring wells are consistent with levels typically observed around the INL (i.e., 1-22 µg/L). Nonetheless, the RWMC chromium concentrations in Wells M1S, M6S, M11S, and M15S are above SRPA background at the INL and increasing. The chromium trend for these wells, as well as elevated chloride and sulfate in Wells M6S, M11S, M15S, and A11A31, continue to be of concern.

The location of aquifer-monitoring wells with elevated concentrations of anions and some metals, especially chromium, are all on the south–southeast side of the RWMC; this may support the hypothesis that a low-permeability zone lies along the south side of the SDA.

6. GEOHYDROLOGIC PROPERTIES OF INTERBED CORES

6.1 Geological Properties

Information presented in this section presents results of a study performed by Laurence C. Hull (INL), Joel M. Hubbell (INL), and Cheryl A. Whitaker (ICP). Samples of interbed material were collected from five wells (see Figure 2-6) in the SDA. Only the C-D interbed was sampled, because the limited material available from the B-C interbed was prioritized for radionuclide analysis. Samples were analyzed for exchangeable cations, extractable iron, aluminum and magnesium, cation exchange capacity, and clay-specific and quantitative X-ray diffraction. Core samples were obtained from stored core material initially collected in the SDA by the OCVZ Project (OU 7-08) between November 2002 and March 2003.

Analysis results indicate that mineral composition of the C-D interbed is about 75 percent quartz, 20 percent feldspar minerals, and 5 percent layered silicates (see Table 6-1). The clay mineralogy averages about equal amounts of smectite, illite, and kaolinite, with a small percent of chlorite (see Table 6-2). Extractable oxides, surface area, and cations are listed in Tables 6-3 and 6-4, and results are generally comparable to those reported in previous.

Table 6-1. Bulk mineralogy composition of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Quartz SiO ₂ (wt%)	Anorthoclase (Na,K)AlSi ₃ O ₈ (wt%)	Albite NaAlSi ₃ O ₈ (wt%)	Muscovite KMgAlSi ₄ O ₁₀ (OH) ₂ (wt%)	Saponite Mg ₃ (Si,Al) ₄ O ₁₀ (OH) ₂ • 4H ₂ O (wt%)	AlPO ₄ • H ₂ O (wt%)
RWMC-1810	DE-3	243.2	81	7	3	7	2	0
RWMC-1813	DE-4	232.7	75	11	8	5	2	0
RWMC-1813	DE-4	239.3	72	9	12	6	2	0
RWMC-1816	DE-6	240	73	15	7	2	2	0
RWMC-1819	DE-7	242.4	75	9	5	8	3	0
RWMC-1819	DE-7	247.3	74	8	9	9	1	0
RWMC-1819	DE-7	248.7	72	10	10	6	2	0
RWMC-1822	DE-8	232.5	68	11	14	1	1	4
RWMC-1822	DE-8	240.5	75	15	0	8	2	0
Average			73.9	10.6	7.6	5.8	1.9	0.4

Table 6-2. Clay mineralogy of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Smectite (wt%)	Illite (wt%)	Kaolinite (wt%)	Chlorite (wt%)
RWMC-1810	DE-3	243.2	31	28	35	6
RWMC-1813	DE-4	232.7	48	28	19	4
RWMC-1813	DE-4	239.3	24	26	45	5
RWMC-1816	DE-6	240	57	18	22	3
RWMC-1819	DE-7	242.4	27	30	39	3
RWMC-1819	DE-7	247.3	0	51	41	7
RWMC-1819	DE-7	248.7	39	25	33	3
RWMC-1822	DE-8	232.5	44	32	21	4
RWMC-1822	DE-8	240.5	29	29	35	7
Average			33.2	29.7	32.2	4.7

Table 6-3. Surface area and extractable oxides of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Surface Area (m ² /g)	SiO ₂ (mg/g as oxide)	Al ₂ O ₃ (mg/g as oxide)	Fe ₂ O ₃ (mg/g as oxide)	MnO ₂ (mg/g as oxide)
RWMC-1810	DE-3	243.2	49.8	5.76	2.87	14.6	0.262
RWMC-1813	DE-4	232.7	31.2	6.4	2.6	17.1	0.218
RWMC-1813	DE-4	239.3	40.8	5.8	2.62	16.3	0.2
RWMC-1816	DE-6	240	17.7	4.12	1.72	12.0	0.138
RWMC-1819	DE-7	242.4	48.1	5.76	2.71	15.4	0.244
RWMC-1819	DE-7	247.3	57.0	4.47	2.51	13.0	0.215
RWMC-1819	DE-7	248.7	50.2	5.09	2.67	10.8	0.254
RWMC-1822	DE-8	232.5	11.7	3.24	1.32	10.8	0.148
RWMC-1822	DE-8	240.5	56.1	5.26	3.0	14.0	0.24

Table 6-4. Exchangeable cations of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Exchange Calcium (meq/100 g)	Exchange Potassium (meq/100 g)	Exchange Magnesium (meq/100 g)	Exchange Sodium (meq/100 g)	Exchange Strontium (meq/100 g)	Sum of Exchange Cations (meq/100 g)	Cation Exchange Capacity (meq/100 g)
RWMC-1810	DE-3	243.2	16.6	0.967	6.05	0.271	0.0301	23.9	22
RWMC-1813	DE-4	232.7	32.2	0.612	4.93	0.253	0.0335	38.0	16.3
RWMC-1813	DE-4	239.3	15.7	0.669	6.09	0.239	0.0264	22.7	12.5
RWMC-1816	DE-6	240	—	—	—	—	—	—	—
RWMC-1819	DE-7	242.4	18.4	0.73	6.72	0.246	0.0302	26.2	23.1
RWMC-1819	DE-7	247.3	19	0.818	6.79	0.22	0.0286	26.9	23.3
RWMC-1819	DE-7	248.7	16.5	0.891	6.15	0.267	0.0273	23.8	21.1
RWMC-1822	DE-8	232.5	25.8	0.31	2.3	0.315	0.0264	28.8	5.4
RWMC-1822	DE-8	240.5	18.1	0.9	6.94	0.388	0.0340	26.3	23.4

These results were compared with previous geochemical analyses performed on core and interbed material at the RWMC using statistical comparison methods, and most parameters were generally comparable. Even though the K_d predictor parameters were comparable to previous values, continuity within the interbeds is not proven; however, results do suggest that geochemical conditions are continuous. These data reinforce the assumption used in the TETRAD model that K_d values are continuous across the SDA. Important variables for predicting uranium and neptunium K_d values were determined to be the sum of exchangeable cations (cation exchange capacity in meq/100 g), exchangeable calcium and magnesium (meq/100 g), extractable iron oxides (mg/g sediment), illite clay fraction, extractable manganese oxides (mg/g sediment), silt, and smectite clay fraction (Leecaster and Hull 2004).

6.2 Hydrologic Properties

Samples for analysis of hydrologic properties were obtained from the uppermost section of the core interval nearest the basalt layer above the interbed and from a distinct coarse-to-fine sediment interface. Only samples from the C-D interbed were analyzed for hydrologic properties. Samples were analyzed for saturated hydraulic conductivity, porosity, moisture content, initial volumetric water content, and dry bulk density. Analysis results of the interbed sediments are listed in Table 6-5.

Table 6-5. Hydrologic properties of interbed sediments.

Well Name	Well ID	Sample Depth (ft bls)	Bulk Density (g/cm ³)	Moisture Content (%)	Total Porosity (%)	Sat. Hydraulic Conductivity (cm/second)
RWMC-1810	DE-3	243.3	1.67	17.3	29.8	1.30E-03
RWMC-1813	DE-4	233.1	1.59	25.7	34.6	2.62E-04
RWMC-1813	DE-4	239.3	1.64	22.9	31.1	7.27E-05
RWMC-1816	DE-6	240.2	1.67	19.4	30.7	5.13E-04
RWMC-1819	DE-7	242.5	1.61	20.9	32.1	7.99E-04
RWMC-1819	DE-7	247.5	1.64	18.8	31.7	1.32E-03
RWMC-1819	DE-7	249	1.79	18.1	23.2	4.54E-04
RWMC-1822	DE-8	233.4	1.60	4.4	35.2	8.33E-02
RWMC-1822	DE-8	240.7	1.50	17.9	37.2	3.04E-03
RWMC-1822	DE-8	242	1.82	12.6	21.6	1.29E-05

Porosity and hydraulic conductivity were measured in 10 samples from five new locations in 2004. New porosity and permeability results were compared with predicted values. Table 6-6 lists the measured values of the new wells, previous values (2002) from the nearest well, predicted values, and prediction intervals.

Table 6-6. Comparison of new C-D interbed core porosity and permeability to model predictions and near-well values.

Well Name	Sample Depth (ft bls)	Observed porosity (%)	Predicted Porosity (%)	Prediction interval (%)	Closest observed porosity (%)	Observed permeability (mD)	Predicted permeability (mD)	Prediction interval (mD)	Closest observed permeability (mD)
RWMC-1810	243.3	29.8	45.20	37.4–53.0	43.02	737.36	476.18	169.3–783.0	321.27
RWMC-1813	233.1	34.6	30.98	26.6–35.3	29.88	271.22	290.74	0–616.1	3.00
RWMC-1813	239.3	31.1	42.10	35.1–49.1	44.2	75.26	504.63	145.9–863.3	339.23
RWMC-1816	240.2	30.7				39.89			
RWMC-1819	242.5	32.1				827.12			
RWMC-1819	247.5	31.7	47.07	43.6–50.6	48.86	1,366.46	230.34	0–524.0	10.80
RWMC-1819	249	23.2				469.98			
RWMC-1822	233.4	35.2				86,231.88			
RWMC-1822	240.7	37.2	48.43	38.4–58.5	43.02	3,147.00	498.98	161.6–836.4	321.27
RWMC-1822	242	21.6				13.35			

All porosity values were less than those measured in nearby wells and less than the lower prediction interval, except for results from Well RWMC-1813 DE-4. Eight of the 10 permeability values were greater than those measured in nearby wells, and six were outside the prediction intervals. Model predictions were not very close to the newly measured values. Although the new data do not agree well with the model, the data agree better with the model predictions than with the overall median. Therefore, it is concluded that modeling the spatial distribution of permeability is an improvement over predicting an overall mean or median for the whole area.

6.3 Summary of Interbed Core Study

Newly measured hydrologic properties for the interbeds beneath the RWMC were obtained and compared to parameter values used in the TETRAD fate and transport model for OU 7-13/14. Geochemical properties were evaluated to test the assumption used in the TETRAD model of continuous, constant K_d values in interbeds for radionuclide retardation. Measured radionuclide concentrations are compared to predicted radionuclide migration.

Geochemical and material properties (i.e., exchangeable cations; cation exchange capacity; extractable iron, aluminum, and manganese; surface area; clay and quantitative X-ray diffraction) were analyzed and the results compared with previous interbed analysis using laboratory, calculated, and statistical methods. Previous work by Leecaster and Hull (2004) provided properties results and statistical analysis of important material properties predictors of K_d . The expected range of these properties was compared with results from this sampling effort. Geochemical and material properties for current sampling are within the expected range for previous sampling, with the exception of slightly elevated oxides of aluminum, which are not identified in previous work as a significant predictor of K_d . The comparability of the new geochemical results to previous results supports the assumption used in the TETRAD model that K_d values are continuous in interbeds across the SDA.

Hydrologic properties were analyzed including saturated hydraulic conductivity, porosity, initial volumetric water content; dry bulk density; and grain size analysis. The results for porosity and permeability were compared with predicted values based on previous interbed analyses. New results were within the range exhibited in previous hydrologic properties sampling. Statistical analysis of results for new permeability and porosity are either within or below the model predictions for these properties in 60 percent of the samples. Small sample size makes analysis of results more uncertain; however, given that condition, the data do not suggest significant bias in the model.

7. SUMMARY

Soil moisture, soil gas, perched water, and the aquifer are monitored around the RWMC to meet a variety of INL needs. Monitoring data were summarized for radionuclide and nonradionuclide contaminants for the shallow (0–11 m [0–35 ft]), intermediate (11–43 m [35–140 ft]), and deep (greater than 43 m [140 ft]) vadose zone and for the perched water and the aquifer. Aquifer samples are collected on a semiannual basis.

The environmental monitoring program at the RWMC serves multiple needs. This report focuses on the needs of two specific activities: (1) continued operation of the Low-Level Waste Disposal Facility and (2) evaluation of the nature and extent of contamination. Although many objectives are similar for the two projects, there are a number of differences in COCs and other specific needs. Thus, separate summaries of data presented in the report are provided in the following two sections in the context of the different needs.

7.1 Summary in the Context of the Comprehensive Environmental Response, Compensation, and Liability Act

Results from the waste zone, vadose zone, and aquifer monitoring indicate that some contaminants are migrating out of the waste zone and into the vadose zone; however, data about the aquifer are inconclusive. Tritium was detected in the vadose zone and aquifer beneath the RWMC, but significant detections also occurred upgradient of the RWMC. It is speculated that tritium is from upgradient facilities, primarily RTC; however, it is also likely that some of the tritium beneath the RWMC comes from sources in the SDA. Uranium is regularly detected above background concentrations in the shallow- and intermediate-depth lysimeters around Pad A, Pit 5, and the western end of SDA. In the deep vadose zone, anthropogenic uranium was detected at one monitoring location in Pit 5 at 69 m (227 ft). Uranium detections in aquifer wells located around the RWMC are representative of natural uranium; however, indications of very low concentrations of anthropogenic uranium were found in two upgradient RWMC wells. Brine contaminants continue to migrate through the SDA vadose zone, as detections in the intermediate and deep regions of the SDA vadose zone (i.e., 11–43 m [35–140 ft] and deeper than 43 m [140 ft]) are becoming more frequent and widespread. This FY, brine was detected in the vadose zone at depths of 115 and 126 m (377 and 413 ft), and there were some indications of brine possibly reaching the aquifer beneath the RWMC. These data appear to warrant further investigation for use as modeling calibration targets or model validation and to assess potential future impacts to the aquifer.

Other results include the following:

- Carbon tetrachloride, toluene, and trichloroethene are affecting the aquifer beneath the RWMC. Affected aquifer wells are generally located east and southeast of the RWMC.
- Concentration trends of CCl_4 in many RWMC aquifer wells appear to be stabilizing, but continue to be detected at concentrations around the MCL in Wells M7S and M16S.
- Chromium concentrations in aquifer Wells M1S, M6S, M11S, and M15S are significantly above aquifer background levels, and have evident concentration trends. Because chromium concentrations in Well M15S fluctuate more than other wells, it is likely that the MCL could be exceeded with future concentration spikes.
- A U-235 concentration trend may be developing in upgradient aquifer Wells M12S and M13S.

- Chemical constituents of magnesium chloride brine have been detected at the 126-m (413-ft) depth in the vadose zone, and may have been detected in aquifer wells east and southeast of the RWMC.
- Uranium concentrations in a few isolated areas of the SDA, between the 0- and 43-m (0- and 140-ft) depth interval, and one at 69 m (227 ft), are significantly elevated, above 1E-05 RBCs, and continue to show both concentration trends and isotopic ratio trends. Some lysimeters have trends indicative of anthropogenic uranium slightly enriched in U-235; however, recent data at some locations show isotopic ratio trends changing in a direction more indicative of natural uranium.
- Technetium-99 is consistently detected at depths to 27 m (88 ft) in Lysimeter Well D06, by Pad A, and Well W23, at the west end of the SDA. The concentration associated with Well D06 is increasing and approaching the aquifer 1E-05 RBC.
- Significant nitrate concentration trends are occurring in two locations in the vadose zone at depths around 30 m (100 ft). The trends are associated with Lysimeter Wells PA02 and I-2S, which are located by Pad A and in the west end of the SDA, respectively.
- Low-level tritium detections in the vadose zone are becoming more widespread and fairly consistent, especially in Wells I-2S, I-2D, and I-3S, and detections are occurring more frequently in Perched Water Well USGS-92. The major source of tritium is likely from beryllium blocks buried in the SDA. The effect that grouting had on tritium is unknown, but will be determined over time.
- Air concentration data from beryllium-block monitoring show consistent annual fluctuations of tritium and a total release of 2 Ci for FY 2004, but with no obvious long-term trend in air concentrations.
- Carbon-14 concentrations around the beryllium blocks are substantially higher than C-14 concentrations near the activated steel or low-level waste disposals, as expected.

Locations of contaminants consistently detected at concentrations above background are shown on Figures 7-1 and 7-2 for the vadose zone and aquifer, respectively. Only monitoring wells showing three or more detections within the past 7 years, one or more of which were recent (i.e., FY 2004) detections, are included on the two figures.

7.2 Summary in the Context of Low-Level Waste Disposal

Chapter IV of DOE Order 435.1 requires that the results of PA and CA modeling be used to design an environmental monitoring program for the disposal facility. The monitoring results are to be used to verify modeling assumptions, confirm that the model adequately represents actual conditions, and demonstrate compliance with RWMC performance objectives. Required data streams for the RWMC PA and CA monitoring program are identified in the PA and CA monitoring program description (McCarthy, Seitz, and Ritter 2001). Most of the required information can be gathered from results of the ongoing INL monitoring programs, but several new monitoring efforts have been initiated to characterize the migration of radionuclides in surface sediment near specific types of waste. Results of the monitoring are discussed in the following sections.

A comparison of the FY 2004 monitoring results with FY 2004 action levels from the PA is made in the annual PA and CA review (Parsons, Seitz, and Keck 2005). The action levels are concentrations predicted at different locations in the vadose zone and aquifer based on modeling conducted for the existing PA and CA. If measured concentrations are below the action levels, then the model

Figure 7-1. Current status of recurrently detected contaminants and their locations within the Subsurface Disposal Area.

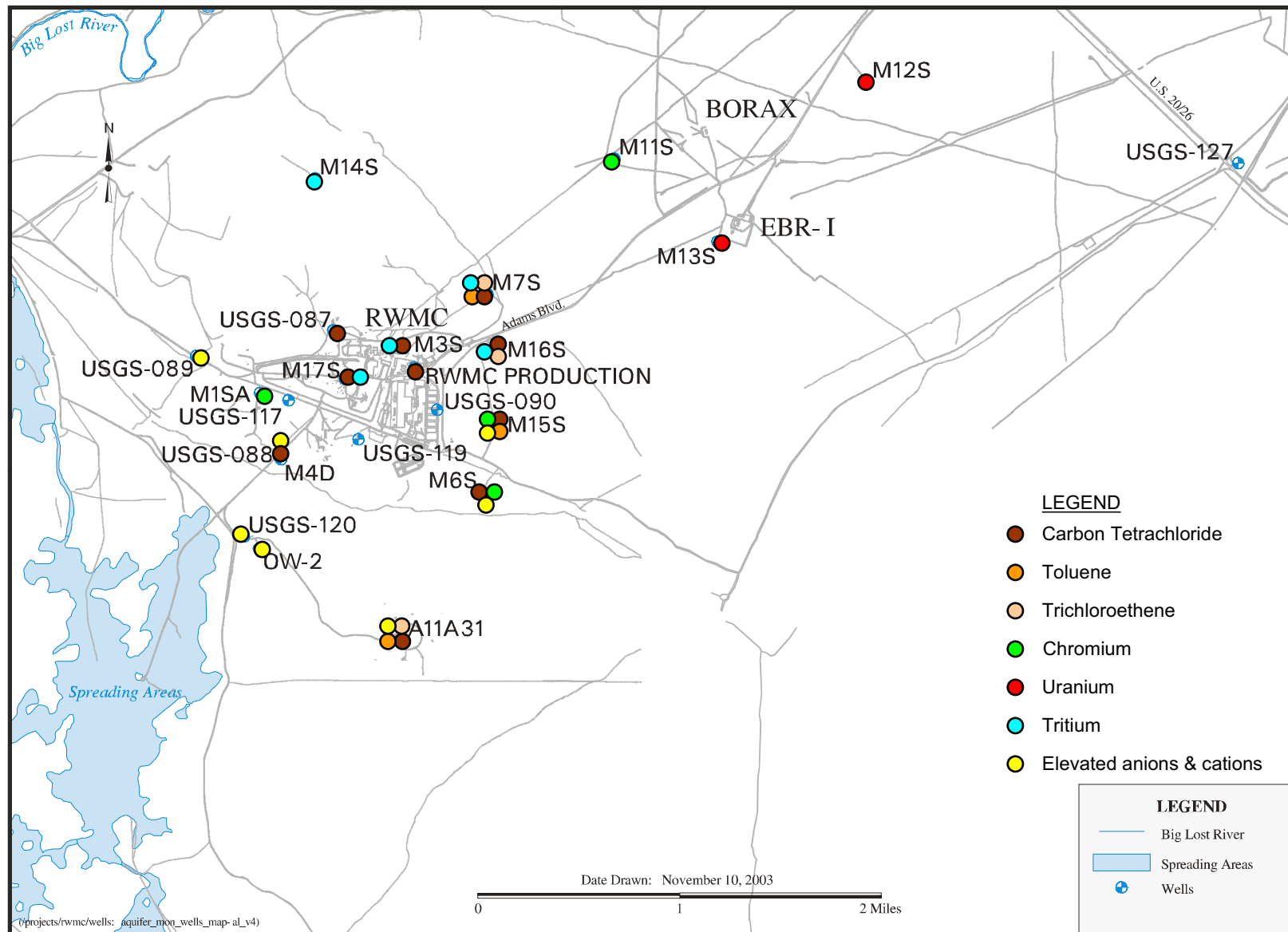


Figure 7-2. Current status of contaminants and their locations in Radioactive Waste Management Complex aquifer.

conclusions about compliance remain valid. The summary information in this report (see Tables 3-9, 3-10, 3-12, 3-13, 3-19, 3-20, 3-21, 3-22, 3-24, 3-40, 3-41, 3-42, and 3-43) is presented in a manner that facilitates identifying the maximum measured concentration at different depths to make the comparison with the action levels.

7.2.1 Summary of Performance Assessment and Composite Analysis Source Monitoring

Source monitoring to support the PA and CA has focused on releases of tritium and C-14 from beryllium block disposals. The Beryllium Source Monitoring Project has produced a useful record of tritium concentrations in the subsurface and atmosphere. Some of the results and methods developed for beryllium source monitoring may be used to find other beryllium disposal locations for the early risk-reduction project. It is evident that long-term monitoring is required to adequately represent the conditions around the buried beryllium. Air concentration data show consistent annual fluctuations, yet there is no obvious long-term trend in air concentrations. The tritium concentration in soil gas has increased at an accelerating rate, and although the concentration must reach a peak and eventually decline, there is no evidence of a peak yet.

Other source-monitoring projects were established to characterize C-14 releases from activated stainless steel and the subsurface conditions in typical disposal pits. The first sampling for the Activated Steel Monitoring Project was conducted in FY 2002, and, as expected, it is evident that the C-14 concentrations are substantially lower than the concentrations found around the beryllium blocks. Sampling equipment and instrumentation are being installed in the active pit, but no data will be available until the equipment and waste have been covered.

7.2.2 Summary of Performance Assessment and Composite Analysis Vadose Zone Monitoring Summary

The vadose zone in the vicinity of the RWMC contains a network of suction lysimeters that allows repeated soil-moisture sampling from soil surrounding the waste and from interbeds in the vadose zone. Data were summarized for the PA and CA radionuclides of interest (i.e., C-14, Cl-36, I-129, Np-237, U-233/234, and U-238). Tritium also was included, because it is a good early indicator for contaminant movement. Maximum concentrations detected were presented for each FY since 1997 and for each depth interval within the vadose zone: shallow (0–11 m [0–35 ft]), intermediate (11–43 m [35–140 ft]), and deep (greater than 43 m [140 ft]). As shown in Table 7-1, data for C-14, tritium, I-129, and uranium are available starting in FY 1997. Data for Cl-36 and Np-237 were not collected until years later. Vadose zone analyses for Np-237 began in FY 2000, and Cl-36 was added to the lysimeter analyte list in FY 2002. The first Cl-36 samples from the vadose zone were analyzed in FY 2003.

In FY 2004, lysimeter sampling results were obtained for all of the PA and CA radionuclides of concern. Iodine-129 and Np-237 were not detected in any of the samples. The maximum concentration of C-14 (4,350 pCi/L) was found in the shallow vadose zone. Maximum C-14 concentrations further from the source term (39 and 185 pCi/L, found at 11–43 m [35–140 ft] and deeper than 43 m [140 ft] bls, respectively) were one to two orders of magnitude less than the aquifer MCL (2,000 pCi/L). Chlorine-36 was detected at low levels in the shallow and intermediate vadose zone with maximum concentrations (up to 32 pCi/L), which is much less than the 700-pCi/L aquifer MCL. Tritium was present in samples from the shallow and intermediate vadose zone and also was present at depths below 43 m (140 ft). Maximum concentrations of tritium were up to an order of magnitude smaller than the MCL of 20,000. Uranium concentrations have been, and continue to be, detected above background for U-233/234 (3.5 pCi/L) and U-238 (1.8 pCi/L) in several lysimeters in the shallow and intermediate vadose zone. In the deep vadose zone, the maximum concentrations for U-233/234 are at about background levels while the maximum concentration for U-238 (3.3 pCi/L) was about twice background levels.

Table 7-1. Summary of radionuclide detections in vadose zone soil-moisture and perched water samples from the Radioactive Waste Management Complex from Fiscal Years 1997–2004.

Sampling Depth Range (ft bls)	Fiscal Year ^a	C-14	Cl-36	tritium	I-129	Np-237	U-233/ 234	U-238
Number of Detection Results/Number of Samples								
Lysimeters 0–35 ft	1997	4/17	NA	13/29	0/20	NA	2/2	2/2
	1998	1/9	NA	3/8	0/7	NA	23/24	24/24
	1999	2/11	NA	3/7	2/9	NA	25/25	25/25
	2000	0/21	NA	3/12	1/18	0/20	62/62	63/63
	2001	NA	NA	NA	NA	0/8	8/8	7/7
	2002	NA	NA	NA	NA	0/5	5/5	5/5
	2003	0/15	3/22	2/7	0/3	0/10	24/24	22/24
	2004	2/28	2/21	10/20	0/13	0/13	22/23	21/23
Lysimeters 35–140 ft	1997	0/1	NA	0/1	0/1	NA	3/3	3/3
	1998	0/5	NA	2/6	0/4	NA	11/11	8/8
	1999	NA	NA	1/1	NA	NA	2/2	5/5
	2000	NA	NA	NA	NA	0/11	18/21	19/20
	2001	NA	NA	NA	NA	0/5	5/5	3
	2002	0/1	NA	NA	NA	0/3	2/3	2/3
	2003	1/15	2/36	4/11	0/4	0/23	33/40	30/40
	2004	2/37	2/35	12/34	0/13	0/11	26/35	21/35
Lysimeters >140 ft	1997	NA	NA	NA	NA	NA	NA	NA
	1998	NA	NA	NA	NA	NA	NA	NA
	1999	NA	NA	NA	NA	NA	NA	NA
	2000	NA	NA	NA	NA	0/2	0/1	0/1
	2001	NA	NA	NA	NA	0/1	0/1	0/1
	2002	NA	NA	NA	NA	0/4	3/3	0/3
	2003	0/6	0/12	0/2	0/1	0/10	6/17	3/17
	2004	0/51	0/33	7/43	0/20	0/15	20/49	12/49
Perched water wells >140 ft	1997	2/2	NA	3/5	0/2	NA	NA	NA
	1998	3/4	NA	3/3	0/3	NA	1/2	1/2
	1999	0/2	NA	0/2	0/3	NA	4/6	2/7
	2000	NA	NA	0/1	0/1	0/1	4/6	4/6
	2001	1/1	NA	NA	NA	0/1	0/1	0/1
	2002	NA	NA	0/1	0/1	0/1	1/1	1/2
	2003	0/2	1/5	0/1	0/1	0/3	5/5	4/5
	2004	1/9	0/6	6/7	0/4	0/2	4/9	1/9

a. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).
FY = fiscal year
NA = not analyzed

7.2.3 Summary of Performance Assessment and Composite Analysis Aquifer Monitoring

Groundwater monitoring of the network of monitoring wells located around the RWMC has been ongoing for many years. Groundwater samples have been collected on a quarterly basis as required for the OU 7-13/14 routine monitoring program, but this changed to semiannual collections in 2004. Data for tritium, C-14, and I-129 were summarized beginning in FY 1997 (see Table 7-2). Aquifer sampling for uranium was conducted from FY 1998 through the present, while Np-237 data were not collected until FY 1999. Aquifer sampling for Cl-36 began in FY 2001 in the vicinity of the RWMC.

Table 7-2. Summary of aquifer sampling results for radionuclides at the Radioactive Waste Management Complex from Fiscal Year 1997–2004.

Fiscal Year ^a	C-14	Cl-36	Tritium	I-129	Np-237	U-233/234	U-238
Number of Detection Results/Total Environmental Samples							
1997	0/7	NA	10/24	1/8	NA	NA	NA
1998	2/23	NA	18/52	2/24	NA	18/18	18/18
1999	3/31	NA	29/73	1/39	0/47	22/44	33/44
2000	9/46	NA	34/79	0/53	0/55	52/53	53/53
2001	5/49	0/15	23/65	0/54	0/62	62/63	63/63
2002	3/45	0/9	20/43	0/53	3/48	46/46	46/46
2003	0/63	NA	28/64	0/78	0/63	63/63	63/63
2004	0/43	0/44	3/37	0/48	1/44	47/49	47/49

a. Fiscal year spans from October 1 to September 30 (e.g., FY 1997 is October 1, 1996, to September 30, 1997).

FY = fiscal year

NA = not analyzed

Aquifer sampling results in FY 2004 were obtained for all of the PA and CA contaminants of interest (i.e., C-14, Cl-36, I-129, Np-237, U-233/234, and U-238) as well as tritium. Furthermore, C-14, Cl-36, and I-129 were not detected in the aquifer (see Table 7-1). Tritium was found in about one-half of the samples collected in FY 2004. The maximum tritium concentration was 1,370 pCi/L, which is below the aquifer MCL of 20,000 pCi/L. Uranium-233/234 and U-238 were detected in all aquifer samples at levels very close to the normal background concentrations at the RWMC. Upper aquifer background tolerance limits for U-233/234 and U-238 are 1.9 and 0.9 pCi/L, respectively.

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